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Towards Deeper Learning with Hand-Crafted Courseware

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Dedication

To Karen Teresa.

Acknowledgements

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Declaration

Some of the discussion and examples presented in this dissertation have been published elsewhere: CBLIS'93[1], CAL'93 (poster presentation), CAL in Engineering[2], EDMEDIA'95[3], CAL'95 (poster presentation) and Computers in Education[4].

The systems, HEART and OLL were generated using the Book Emulator[5], a Silicon Graphics Indy, and Unix-compliant C code. Various gnu utilities were used for manipulating graphics and SGI utilities were used for recording audio.

Abstract

Deep learning will ensure that tertiary students fully understand the implications of what they are taught. However, deep learning requires the students to actively engage in their education. It involves maintaining their motivation and building good learning practices. Computer-based education (CBE) has identified the need to promote deep learning yet to achieve it, teachers must take one of two options. They must either construct their own CBE environments or adopt a preconstructed environment. Teachers need to construct their own educational environment but this is not always successfully achievable with a computer system.

CBE environments that are constructed by teachers require them to make use of tools. In the past teachers had to author any kind of educational environment themselves. With physical media, authoring can be daunting but a familiarity with the tools makes it viable. With computer media, the tools (programming languages, for instance) are unfamiliar which makes the authoring task harder. For the students, the CBE environment must also satisfy their needs. Thus the authoring tools must still result in a profitable CBE environment. Several CBE environments exist to satisfy deep learning requirements. However, very few of them can be easily hand-crafted using any tools provided.

The thesis presented in this dissertation suggests that it is possible to obtain theoretical deep learning with CBE whilst exploiting tuitional skills directly. The solution requires that courseware authoring systems are designed optimally for the educational users' requirements. These are i) familiar media usage and ii) interactive dialogue support. By stating the procedure and protocols for system design it is possible to sustain the usability of future CBE authoring mechanisms. Two authoring systems are described to highlight the effectiveness of the design protocol. The first implements a method for constructing educational prose for pre-requisite learning. The second identifies and implements the construction and use of arguments for deeper learning. In both cases the interactive metaphor for the student and for the teacher is both educational and familiar.

Chapter 1

Introduction

Two combined themes run through this dissertation towards the aim of the thesis. Firstly, students should be able to work towards a deeper appreciation of academic material than with other CBE systems. Secondly, teachers should be supported in their sole creation of the material necessary for deep CBE-based learning. These themes depend upon each other; as Koumi[6] stated:

> "If the teachers can create an enduring fascination for the subject-matter, the job's almost over: the more the students love the subject, the less help they need in their studies." *(p. 134)*

To introduce the research described herein, three orientations are used: i) 'Conceptions' of CBE will highlight general areas covered in the dissertation, ii) 'Directions' of CBE make more specific areas in the conceptions clear, iii) lastly, 'Themes' of CBE are detailed to indicate the necessary objectives for this thesis. These three orientations are discussed within the two themes of the thesis. Those of deeper learning and of hand-crafting courseware.

1.1 Towards Deeper Learning

Two conceptions of research towards deeper learning are investigated by this dissertation. They are research into educational psychology, and some educational contexts (or institutions).

Psychology

Educational psychology research examines many areas of the human learning process. These range from the learner's early development of cognition and memory to the actual curriculum for teaching particular subjects. A locus of control can go from the student to the teacher. This has led to methods for organising the environments of learning. Furthermore, there has been work to understand how to measure the outcomes of the education process.

In particular, educational psychology can provide methodologies for teaching and theories of learning. These methods will guide future teaching towards improvement, and the theories will enable the analysis, description and evaluation of any learning outcomes. Links can be made between the psychology of learning and the psychology of motivation[7,8]. Activity which is motivated usually has some outcome to be remembered. Often motivated activity is the result of a desire to discover something new and learn new information.

Institutions

Research into educational contexts revolves around all the institutions of education from primary school to industrial training. Subsequently, any learning or teaching system will have to exist in some educational context. For example it may be used in academic establishments (schools, universities) for teaching academic skills. Alternatively it could be used in the home or the office for practical training and distance learning.

As a result of the emergence of the home computer market towards the beginning of the 1980's a steady trend has been encouraged in the western world for parents to buy computers for their children for educational purposes. In schools many computer literacy programmes have been set up. This "boom" in home computers has led to a large investment in software development. This explosion of accessibility of computers has not been accompanied by better CBE software.

Much of the investment has been on computer games for the home market rather than education. However once the need for games has been satisfied, the hardware can be used to satisfy the demand for education. Many homes have some form of computer-based entertainment system for which education software could be written[9]. Now that many of the logistical problems have disappeared, home computers and video games consoles might be used for more educational purposes. At the tertiary education level many students have access to a computer which comes with packages for word processing and home finance. Students of the 1990's have grown up in the age of computer literacy and are less "technophobic" than many of the older generation. This means that whilst a vast majority are still ignorant of the underlying technology of computers, their ability to use applications is much greater. Thus, deep learning can be achieved in various educational contexts with suitable computer tools. The time is ripe to advance the use of CBE materials.

Mechanism Directions

To make use of CBE for deep learning, quite advanced mechanisms for information preparation and dissemination must be used. Intelligent systems techniques may be utilised to generate artificial teachers. These might enable the real teachers to reproduce their normal activities in a fashion which is at the demand of any students. To explore and explain complex theoretical knowledge, students can be allowed to practice with experiments. Simulated environments have world models that teachers will have defined. As an alternative to both simulations and ITS, the use of the computer for deep learning can operate at cognitive levels. Tools for structuring and reorganising units of information can develop deeper understanding in students[10]. As an extension of this towards higher volumes of information, hypermedia is considered to be helpful. Accessibility of information may be important for ensuring students are not restricted to education which is unsuitable for their individual learning strategies and techniques.

Motivation Themes

In this thesis, motivation in education is considered as a means of improving deep learning. Tools and mechanisms which can advance this are highlighted. The task of creating an enduring fascination for particularly unmotivating topics is not an easy one and not one to which teachers look forward. The ability to motivate depends on the conditions that are present in the environment in which students are learning. It is practically impossible to **make** people learn: except by using highly reinforcing stimuli which will eventually lead to resentment and rebellious behaviour. The correct conditions are defined by knowing the needs of the student. These conditions can be achieved by incorporating satisfaction of these needs in both the computing environment and the world around. Hence it is necessary to develop an understanding of the motivational requirements of students and their satisfaction by teachers. In particular, these aspects must be explored in current mechanisms and directions taken by CBE systems.

1.2 With Hand-Crafted Courseware

Similarly to deeper learning, two research concepts exist towards hand-crafting courseware. Firstly, the financial costs and rewards, and secondly the technological barriers.

Finance

The integration of a CBE system into the desktop environment is the only forseeable option for the future. Having a dedicated CBE environment such as that envisioned with the PLATO system[11] would not be cost effective in tertiary education despite the proponent's protestations. For tertiary education, the lifespan of course material can be very short and thus teacher generated material is optimal.

Yet, the cost of teacher generated courseware must be weighed up against its effectiveness. Courseware which is produced must be more effective for teaching than traditional methods. Alternatively, the extra costs must improve the efficiency of teaching. For instance, an automated system could serve more students interactively than a single teacher. Furthermore, teachers will have pressures from various stake-holders to gain high levels of student performance whilst individually requiring recognition for their own achievements. Supporting the teachers in the production of material that fits both their own requirements and the students', constitutes a focus of the research described in this dissertation.

Technology

The application of information technology (IT) to education has been suggested as being extremely promising for many years. The advantages of improved efficiency are always promoted because IT can unerringly repeat many tasks. Information technology is ideal for managing the flow and control of electronically storable data. Similarly education manages and controls knowledge and understanding in an experientially verbal or visual form for students. With IT, the management and flow-control of raw data for searching and calculation is well developed. Detailed numerical analyses can be designed and made explicit. But the management and control of learning is less mathematical and must be programmed or authored by the information providers themselves. Rules must be defined to structure teaching and learning practices.

The construction of educational material upon a computer is very different to many forms of information creation and distribution. Not only is raw data required but the interactive program must interface with the students. Various techniques for utilising technology for authoring have been adapted or adopted from electronic publishing, internet authoring and user interface design. Standards for document preparation, such as the Office Document Architecture (ODA), and the Standard Generalised Markup Language (SGML)[12], hold possibilities for authoring courseware. Also, a hypermedia-based extension to the original SGML system is available called HyTime[13]. Lastly, programming techniques and paradigms might be adopted from research into object-orientation, minimalist scripting and visual programming.

For students and teachers, the universities are also encouraging widespread IT usage in the educational environment with word-processing courses and network connections in college rooms, teaching laboratories and lecturers' offices. Systems using window-based user interfaces, mouse and keyboard are more commonplace and understood than they were 10 years ago.

Integrated networks allow for a more active educational environment with access to library catalogues and word processors. The inclusion of electronic mail gives a very good method of communication between the students and lecturers. With an increased band-width[14] (i.e. more than just typewritten text) passing between the lecturer and student, possibilities exist for more advanced forms of distance learning.

With the advent of new technology it is necessary to appreciate the fears, attitudes and expectations that users have when making use of their computers. Research findings of the psychology of computer users has been available for some years[15,16]. In the beginning it was concerned with how people responded to instrumentation in any type of machine that they were using. Yet now, most of the current research literature looks towards human-computer interaction. Considering HCI in terms of the CBE users enables researchers to make valid judgements about interaction strategies.

Practical Directions

The directions taken to adopt technology whilst remaining within practical limits involve two opposites. These are either the reuse of existing technologies, or the development of specialised tools which ultimately result in improved final course material. The reuse of tools such as those for desktop publishing are obvious for teachers who wish to typeset their courses. Alternatively, the students can be provided with IT tools, such as those they will eventually use in industry. These can allow them to experiment and practice. Billings et al. note the use of the computer as a tool, a teacher or a tutee in their historical perspective of CBE[17].

Beyond the reuse of computer tools, new tools for education are implemented in two forms: authoring systems or dedicated environments. Like a standard tool, the latter dedicated mechanism can only be adopted by the teacher. The advantage is for the student, who gains a professional tutoring system geared to their general requirements. For the teacher to gear such a system to specific needs requires flexibility to be incorporated. Alternatively, the teacher can generate the courses themselves using an authoring tool.

Construction Themes

This dissertation focuses on the design and use of authoring system for hand-crafting courseware. Hand-crafting courses can be achieved most specifically in tertiary education through the programming of dedicated material. The challenges facing the hypothesis are to ensure that the computer-novice teachers are supported. They must be able to take advantage of the computer for instructional design in particular. Therefore, the challenges must be overcome with design protocols. Lastly, the courseware produced must interact with students to satisfy their requirements for deep learning.

1.3 Dissertation Preface and Outline

Computers are used as vehicles for education, both by teachers and by learners. However the teachers and the learners seldom directly affect the outcomes of the other's use of the computer. That is, the students' and teachers' outcomes are defined by commercial courseware rather than each others' direct requirements. Therefore more emphasis is required on placing "CAL into the mainstream"[18]. The research identified in this dissertation aims to make this possible by improving the instructional providers' ability to design and produce their own digitised material. This material should be both efficient and effective for instruction whilst remaining engaging, active and motivating for learning. Two main themes highlight these aims. Firstly, deeper learning should be promoted through appropriate student working methods. Secondly, both the student and the teacher should be able to interact with the computer directly to produce a total environment for education.

Tertiary education has many opportunities for teachers to make use of computers for assisting in education. Teachers are a scarce commodity which must be made available to increasing numbers of students through various media. Students similarly must work actively with these resources to gain the most benefit.

Deep learning at any level requires students to think actively. Cognitive research has utilised a number of mechanisms for CBE that aim to train students in this highly important skill. Namely, concept map creation, studying through hypermedia and working with expert systems. The promise that they might help to improve deep learning is valid. This is because they require the students to think actively towards the "solution paths" they give to the computer to gain rewarding feedback.

For tertiary education, the courseware must always remain contemporary. Thus the teachers must have direct involvement at the key educational level as the courseware is being produced. However, the courseware must always remain useful to the students. This means that the interface quality of both the authoring mechanism and the final courseware can often rely upon the talents of the teachers and students. These talents must be supported and catered for.

This dissertation describes the outcome of developing novel computer-based educational environments in tertiary education. These environments will allow the lecturer to generate their own course material in a manner to which they are accustomed. The courseware must be available to students at a time when they require it and promote a deeper understanding of the material to be learned. By following research aimed at practical issues this dissertation will investigate and improve the areas of CBE that encompass techniques and strategies for automated and individualised education.

chapter 2 - The strategies and methods for learning and teaching that have been the basis for most, if not all, CBE are described. CBE must obviously try to satisfy the students as they learn. Much research has looked into the motivation of human beings and also the methods for motivating students. Student learning is best when motivated and the teacher must take the opportunity to provide an invigorating environment. This chapter will discover how this might be possible.

chapter 3 - In contrast to chapter 2 this chapter describes various systems and their abilities to satisfy the real requirements of the teachers and the students. The criteria which teachers might use are based upon their need to craft their own courseware. The students requirements are also considered in terms of the deep learning outcomes.

chapter 4 - Before the student can be given any CBE it must be authored. Authoring techniques, both using a computer and without, are examined here and their implications for the teacher are given. It examines some of the common authoring mechanisms in use for CBE and assesses their usefulness before describing a new method of design. This method tries to overcome the inefficiencies of previous authoring methods. A model drawn from traditional issues of course design is given.

chapter 5 - Considering that two contexts of learning exist this chapter attempts to work towards solving the first of these. Prose learning comes from understanding material that is delivered passively. The most common place for this to occur is in the lecture. The lecturer organises and presents information in ways that can be absorbed quickly. In order to make the lecturer more accessible to the student a system for on-line lecturing is described in this chapter.

chapter 6 - The second context of learning is the tutorial classes. This is not so simple to implement because of the interactive and dynamic nature of problem classes and tutorials. Nevertheless, factors so far investigated are brought together and result in an idea for the combined improvement of courseware construction and usage. This idea uses argumentation as its premise and the implementation of a system for on-line argumentation is discussed.

chapter 7 - An evaluation of the systems is necessary to make qualitative statements. It is difficult to gain sufficient results from user testing in the short time of a D.Phil. thesis, hence an internal cognitive analysis is presented along with a small-scale external analysis. These will highlight the problems and benefits envisioned with the CBE systems. It will also point towards future experiments which might be done and the anticipated meaning of the results.

chapter 8 - Conclusions of the thesis and its contribution to knowledge are given in this chapter along with possibilities for future work.

Chapter 2

Teaching and Learning Methodology

This chapter is mainly concerned with the *cognitive* processes of learning and their support through teaching. Good teaching aims to exploit these processes by satisfying the questions that arise in students during tuition. That is by taking learning theories and attempting to link them to principles for instructional design[19]. The cognitive approach to learning is shown to be more useful for understanding education, and it enables researchers to understand how a student might approach a computer-based learning system. In contrast, a *behaviourist* view of learning cannot adequately describe why certain responses to learning occur in humans. For example, it cannot describe why giving rewards or punishment might be interpreted differently by people - some might try harder, and some might give up.

Much research exists for educational psychology (see[8,20] for introductory texts) and it consists of thought development in children, human memory capacity, strategies for knowledge retention, behaviour modification, and so on. The motivational factors and problem solving strategies that invoke deeper learning can be identified through cognitive theories. Cognitive research has also guided instructional theories and produced valuable instructional methods. This should provide the necessary information to generate a strategy of instruction and learning which might possibly be used to guide CBE implementations.

This chapter is organised into three sections. The first discusses how motivation affects learning. Without some form of motivation real learning will never take place. The right array of motivators are required to ensure that the right kind of learning is taking place.

The second section discusses in more detail the procedure of learning. This is described in terms of the cognitive processes which are occurring in a student. Research has been done to validate these processes and some of this evidence will be presented here. It describes the strategies which students might adopt to gain the most from education.

The last section indicates some of the principles which teachers should use to support their students. Furthermore, this section will describe how a teacher can influence the learning environment both statically and dynamically; that is, with simple prose that a student can passively study or with tutorial classes in which the student can actively engage.

2.1 Motivation in Education

Motivating students to learn is an activity which teachers constantly have to do and which if successful will benefit the students. Since students' needs drive their motivation, the major factors that influence individual needs are discussed. By understanding human motivation and how it can be influenced, it is hoped that the correct conditions for keeping students interested and active can be generated within an educational environment.

2.1.1 Needs and Desires

Before going on to show how the learning environment can be influenced by the teacher it is important to notice that learning occurs naturally as a result of the satisfaction of needs and desires. Need fulfilment is the keystone to most conformist theories of motivation. Child[7] describes a cycle of events which leads to learning that is motivated by the fulfilment of desires. In the beginning there is a need, albeit instinctive, innate, or suggested, that is desired. It is the desire to reduce the strength of this need that drives and motivates activity. The desire for satisfaction leads us to learn how a need can be reduced by the correct application of cognitive effort. This sort of learning constitutes the forming of habits.

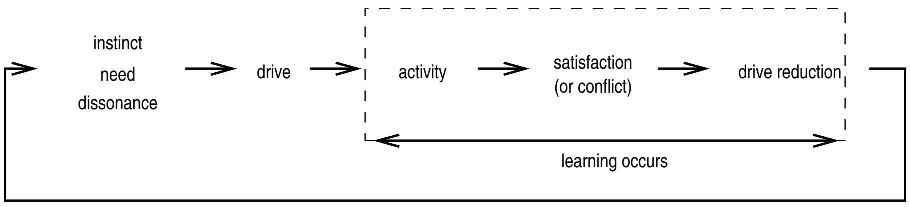


Figure 2.1: A simple model of motivation

This model shows how learning is part of the cycle which is naturally occurring during the satisfaction of our desires. When this natural cycle is imitated, needs which are desirable enough to require satisfaction are created manually. This sufficiently induces the motivation to work actively.

The motivational psychologists have two strong theories for assessing what are the needs of the individual and how these can affect their patterns of behaviour. The *cognitive* approach takes into account the expectations and beliefs of the individual whereas the *behaviourist* only alters external stimuli (S) and observes the external responses (R): S-R. By concentrating on the reasons *why* people are motivated, cognitive psychologists believe it is possible to understand how people can be motivated to learn. This view of the human as an active participant with motive is known as **organismic**[21].

Thus, if someone is going to be motivated they must have *needs*. Needs can be generated from two origins: intrinsically and extrinsically. However they all must occur at an individual level. One of the most famous motivational theories for management that considers the level of the needs of the individual is Maslow's Hierarchy of Needs[7,22].

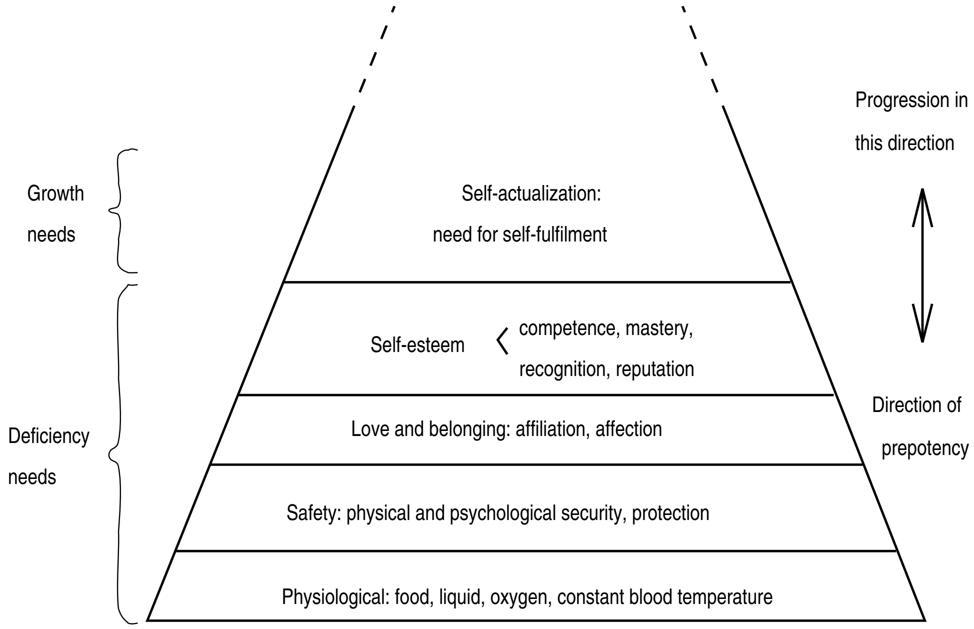


Figure 2.2: Maslow's hierarchy of needs

The hierarchy emphasizes that needs rise from basic primeval and physiological needs to those for self-actualisation (i.e. the need to satisfy self-designated goals). The lower needs must be satisfied sufficiently before higher needs arise. The basic needs are not generally useful when trying to motivate at an organisational level but the upper needs are. The need for power, affiliation and achievement are all possible motivators[23].

2.1.2 Extrinsic Motivation

A position can be assumed which says that all behaviour is in response to external stimuli and contingencies in the environment alone. This contradicts the theory that people have intrinsic needs and desires that can be fulfilled, although it is related since the observations made are effectively the same. The difference is that adequate explanation for why the response occurs is not available. This is the **mechanistic** or behaviourist view of a human as held by a large body of psychologists[21]. The mechanist views the human subject as a passive organism that only behaves according to externally observable conditions (e.g. physiological states such as satisfaction or pain). By viewing and affecting these conditions it is possible to theorise about their function.

Two forms of conditioning are evident: classical and operant. Classical conditioning is simple to understand and happens when an active stimulus strengthens desired responses and removes undesirable ones. Thorndike (1911) (also in Mayer[20] , p 88) originally identified this strengthening of positive responses to stimuli and called it his "law of effect". This trait is observed in the conditioning of animal reflexes (e.g. Pavlov's dog in Child[7] - chapter 5). Operant conditioning, introduced by Skinner as an extension to Thorndike's law[24], suggests that after a desired response to a particular stimulus some kind of reinforcement (positive reward or negative punishment) should be presented. In future, the subject will *operate* on its environment to receive a similar reward. The interrelationship between these factors (stimulus-response-consequence) are the contingencies of reinforcement[25].

Thorndike's and Skinner's theories were the very mechanisms that were often used in schools in the middle of the 20th Century. To ensure desired responses in children they were offered rewards or punishment for particular behaviour (response to stimulus). As a result, the child would be conditioned to expect a known consequence to similar behaviour. A common and necessary type of operant conditioning is the *tact* response utilised when a child learns its first language[7]. Touching a table and saying the word "table" familiarises the child with the correspondence. The child will then operate on the environment, using the word "table" to make itself understood. On occasion, teaching practices such as achievement tables and continual assessment present both rewards and punishments because of their competitive nature. Using assessment without feedback is liable to generate negative reinforcement.

Of course, there are other mechanistic views which are based on physiological needs such as Hull's[21,24] four basic tissue needs: hunger, thirst, sex and avoidance of pain. For example, in a similar vein to Hull, Freud suggested that two basic *instincts,* sex and aggression, could explain the psychic processes and patterns of maladaptive behaviour in his patients[7,24,26].

Usefulness of behaviourism

It can be seen that these theories of motivation are a way of predicting the outcome of stimulus. However, they often seem to predict human responses incorrectly. An explanation for this is that all the past experiences which a person has had can never be fully known[24]. This suggests that behaviourism is impractical since it does not consider the affective processes of the human mind. To know the experiential history and current contingencies of a person is too complex and hence utilizing it to predict behaviour is effectively impossible[21] (p 8). Furthermore, controlling people with basic physiological needs and reinforcements in order to motivate them may be resented and induce rebellion.

The use of such control should not be ignored and has been applied in management situations. In Hamner's paper[25], stimulus-response bonds or contingencies can be created using four techniques: positive reinforcement, avoidance learning, extinction and punishment. However, six rules have to be remembered when implementing these contingencies: do not reward everyone the same, giving no response can have reinforcement consequences, say what actions will be reinforced and what actions are wrong (so bonds can be formed), always punish in private (to avoid unexpected bonds in observers) and finally make the consequences equal to the behaviour.

2.1.3 Cognitive Psychology

Cognitive theories were founded from behaviourist theories. The effect that goals have on mechanistically driving people were investigated; but, having goals does imply that some form of cognition is evident and that people are making their own decisions. An early exemplar of a more cognitive view of motivation was Lewin[24]. Lewin's view was that tensions build up according to how much unfinished business exists. In order to relieve these tensions and return your physiological state to normality (a Gestalt whole), goals would have to be set. It was the idea of having a believed direction towards some desired future state and not the internal involuntary tensions, that has been most useful to the cognitive psychologists that continued the work. However, goal driven theories are still mostly concerned with the *process* of motivation (what is driving the individual) and not the *content* (why they are driven) (p 14)[24].

When studying the aspects of setting goals, Latham and Locke[27] found that specific goals worked best for their experiments with free-lance loggers. As a result, the report suggested some rules for goal setting.

- Firstly, the goals must be specific and have some time limit, challenging but reachable. In the case where the goal is harder to attain, the performance would be better. It was difficult to say whether individual or group goals should be set.
- Secondly, commitment to the goal should be obtained. This does not require threats or even rewards. In the studies, merely fair goals were sufficient so long as supervisory support was present. Supportiveness is critical before goals increase motivation. They should help to clarify what is expected and not just impose deadlines.
- Finally, there should be elements to support the completion of the goal in whatever way possible. Such things as company policy, inadequate resources, and so on should not interfere with the freedom to achieve success.

2.1.4 Intrinsic Motivation

Acting according to a hedonistic desire is *intrinsic* motivation. The learner could be motivated to learn due to internally generated needs and desires. So far, behaviourists believe that responses directly result from learning built upon all previous stimuli. The cognitivists, on the other hand, try to understand why people are motivated by considering the processes that occur internally within the person. Desires are originated, maintained and fulfilled by individuals. They may be extensions of basic needs or they may stem from an innate desire to explore and discover.

Originating Desire

The major starting point comes from White's[28] work on the concept of competence (need for efficacy) and de Charm's[23] work on personal causation (origins and pawns). Whereas behaviourists believe that stimuli generate responses, intrinsic motivation describes how activity can be rewarding in itself. The stimulus is to satisfy the growth process.

Dissonance theory[21] has shown that if two conflicting factors exist, dissonance (a discomforting feeling) occurs. This is another intrinsic motivator which causes a person to try and reduce that dissonance by attributing it to some externally justifiable cause. If no possible reason can be found then they will change their own view in order to reduce the dissonance. That person must feel responsible for any action that causes dissonance for them to change their view. Intrinsic motivation is increased while they work to alter their own viewpoint to justify their actions.

Persistence of both children and adults to reach some level of mastery suggests that they have a strong desire to achieve self-efficacy or self-esteem. Perhaps it is the fear of failure which can increase the desire to achieve[7]. Some level of aspiration is usually required to motivate achievement. Without some help at setting realistic goals and discovering self-capabilities, it is difficult for many to attain high results.

Maintaining Desire

Deci[24] describes Rotter's (1966) *locus of control* which, on one side, indicates a person's general expectancy that their behaviour will reliably lead to a desired reinforcement: this is the *internal* locus of control. The *external* locus of control indicates that the individual expects that their behaviour will **not** reliably lead to any form of reinforcement. The internal locus of control motivates action since there exists an expectancy that a need will be fulfilled whereas the external locus is most often associated with negative job related aspects[29]. To abstract these expectancies into a theory Vroom (1964) (described again by Deci[24] and

Pinder[30]) drew up a system that could equate a motivational force to the expectancy of a reward and the valency (your attributed value) of this reward[31]. In other words, you would be motivated towards doing a task because you felt that it would in some way be to your benefit.

By bringing together the work of Georgopoulous *et al.*, Vroom, and Porter and Lawler, Handy[23] developed a motivational calculus. Every person uses it to decide how motivated they are towards any task. The factors that initiate this calculus include needs, results (outcomes) and 'E' factors. The 'E' factor represents effort, energy, excitement, expenditure and so on that an individual may put into the calculus. These factors are given subjective strengths by the individual such as the *salience* of the need, and the *expectancy* that an 'E' will return a result that will be *instrumental* in reducing that salient need. They are all based on a belief which leads towards motivated behaviour[30]. The equation is also multiplicative so that a zero of any factor will result in the motivation being zero. The calculation can be conscious or unconscious, calculated or instinctive.

Fulfilling Desire

The fulfilment of desire will affect how an individual is motivated in the future. The primary way of knowing that desires have been satisfied is from the feedback which will be provided[20,32]. Often rewards and punishment are used as reinforcers like the positive consequences of responses in behavioural psychology. However if this were the case then food or sex might be the only stimulus that humans required to 'stamp-in' † Thorndike's SR bond. This is not the case and hidden costs are known to be associated with such tokenistic schemes. These costs originate because the individual will consciously relate feedback to the activity which was motivated. If activities were motivated because of a particular reason, such as personal satisfaction, and the feedback was a reward such as money; the motivation would change in the future; i.e. desires for personal satisfaction would be replaced by desires for money. The individuals change their attribution and assessment of future success from personal gain to financial gain.

† This is Thorndike's terminology.

If desires are to be fulfilled they must be rewarded carefully. Feedback that is in support of motivation can be intrinsic or extrinsic. Intrinsic feedback results from what is directly observable from the actions which generate the feedback, whereas extrinsic feedback may occur out of some less direct result. In this case the feedback should be in the form of a satisfier rather than a reinforcer. The original goal needs to be understood before feedback can be successfully administered. Individuals must be able to know that their activities have succeeded and that it has satisfied their need. Mechanistically, this is difficult because it requires discovering or uncovering what the need was in order to satisfy it effectively.

2.1.5 Implications for Learning

Understanding the motivation to learn cannot be purely based upon the individual's responses to stimuli. Different responses can occur after similar stimuli have been presented in different situations or to different people. This stimuli can be a reinforcing reward or the suggestion of painful situations. Thus, the theories of behaviourists does not match the actual result of experiments undertaken in education.

It is more productive to analyse the possible cognitive processes which might be at play. Research suggests that it is the interpretation of feedback and reinforcements that might be used to induce motivation to work. This turns out to be a more suitable representation of Thorndike's Law of Effect (Stimulus-Response). By further analysing the way in which a student's stimuli or **goals** are created, maintained through **activity** and fulfilled through **reflective feedback**, a method of improving the student's tuition may also be developed. This tuition, on the whole, will be motivating and engaging. Education can now be explained in terms of its ability to satisfy the motivation that is required.

2.2 Procedure of Learning

A simple model of the activity of acquiring new knowledge has resulted from the culmination of papers concerned with modelling instruction and learning[7] and the experience of learning[33]. All the models view the learning 'event' or *lesson* in three basic stages: **P**resage, **P**rocess, and **P**roduct[34]. The 3P model below shows the cyclic nature of instruction and learning which can occur in lessons of any length, and may occur many times.

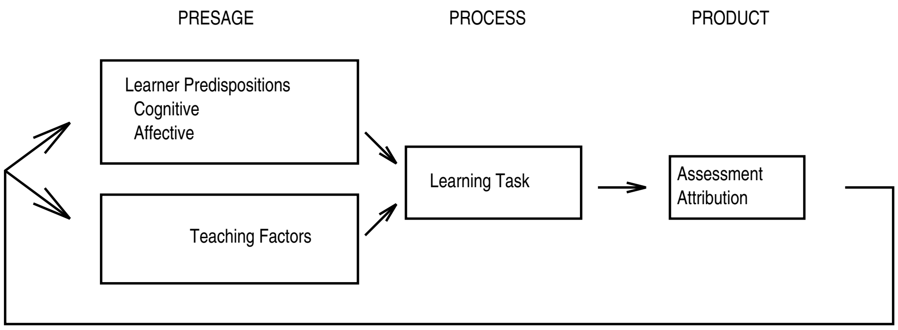


Figure 2.3: A simple model of instruction

Before learning starts there is the **presage** which introduces factors into the lesson from the instructor and the learner. Thus the learning outcome is subject to the individualities of the students and teachers. During the **process** of learning there are tasks which must be executed in order to build new concepts within the student. Tasks can be guided by the learner or by the instructor in order to *acquire* new knowledge or *apply* it to new situations. Lastly, the intended **product** of learning is to ensure that the learning tasks are understood so that learning in the later stages can build upon the earlier material. This is so that the new understanding can be appreciated. Subsequent learning will follow the same sequence utilising the new understanding.

2.2.1 Before Learning

The *presage* describes the predispositions of both the learner and the teacher. What the student brings to the lesson is as important as what the teacher is going to give. The quantity and quality of what is learned depends upon the student's approach to learning: in essence, how much they want to satisfy their need-to-know. As a student begins a lesson, two 'entry' predispositions[7] manifest themselves. These are cognitive and affective predispositions (see figure 2.3). The first describes the knowledge and abilities of that student, and the second describes the interests and self awareness (belief of competence). These predispositions will generally affect the performance of the student despite any motivators.

The attitudes that the students bring are based on prior experiences. These centre on two ideals that depend upon the interests of, and the abilities towards, a topic. These ideals are the *quantity* of knowledge to be gained and, the *quality* or meanings to be ascribed to that knowledge. A third and related ideal is the concept of *institution*. This is the quantity and quality of knowledge that is required in order to get through the institutional examinations and assessments. All the attitudes contribute to the student's selection of an approach to learning.

Approaches to learning are based on the motives and strategies that the student has in addition to their attitude to learning. The motives (reasons) may be *extrinsic*, suggesting that the approach taken is a means to an end, or *intrinsic*, an end in itself. As a strategy for satisfying these motives the student can utilize proactive approaches, reactive approaches or achieving † approaches[34].

When a student approaches a task the amount they will learn depends on their aspirations and intentions. The strategies indicated by deep and surface learning are mutually exclusive. Surface learners have a desire to gain answers to satisfy initial desires only. These are usually extrinsic desires, which are often remote from their personal goals. To do this, they may simply memorise the information that seems most important. Deep learners, on the other hand, aspire to have a personal understanding of sophisticated concepts. The student will critically assess the information, relating it to prior experiences and re-discovering what may have led to any conclusions that have been previously reached[36]. Marton and Saljo[37] give a detailed discussion of these approaches to learning including how they relate to student motivation and to the process of learning. In other cases, the

† Not to be confused with achievement motivation.

level of learning is accredited to the student's motivation to *achieve* the goals that have been set. Many psychologists have researched the field of achievement motivation exclusively[7,21,38,39,40]. The need for achievement, social affiliations, and psychological needs provides the drive towards activity as demonstrated by cognitive psychologists.

Both these approaches are related to the motivation to achieve and this, in turn, is related to their level of aspiration. Again, this level is dependent on the student's past experiences. For example, repeated failure means that a student has difficulty setting realistic goals for themselves and may lower their aspirations in future to ensure success - nothing can enhance failure in quite the same way as failure[7,38]. Yet, if the student had a series of *easy* successes, the level of aspiration may also be set low. So it is important that challenge is maintained though not so much as to impose failure: achieving these greater goals actually encourages higher aspirations. McClelland[38] discovered that success followed by failure in equivalent tasks can improve a student's need for achievement. This is possibly due to them feeling a sense of aspiration to fulfill a goal that is known to be achievable.

DeCharms[41] argues that giving students personal responsibility should enable them to provide themselves with the best approach to learning. However, learners should not be left in total control because they may not necessarily be the best judge of what to learn. Students must be proficient at planning their own learning and they must have some idea about what they want to learn. Success is only achievable when prior knowledge of the subject domain is sufficient.

2.2.2 During Learning

The *process* or procedure of learning is dependent on the student's own goals and upon the demands of an instructor. Here any approach which the student deems suitable or to which the student is accustomed is taken. Learning requires two phases of knowledge acquisition in the conventional educational setting. Knowledge of facts and concepts is the first, and the methods of applying that knowledge to real world problems is the second.

Students have many **styles** of learning and the classic examples of these are the serialist and holist style[36]. A student's style of learning shows how the student processes the information that is available and not what quantity or quality of learning that is achieved. The serialist processes information consistently from start to finish assuming that the given order is appropriate for learning the material. The holist will try to get an overview of all the relevant material to whet the appetite for what will come in the main text by, for example, skimming through a book reading the introductions before actually settling down and reading it through[42].

The activities which a student can engage in to learn new topics define the quality and quantity of information learned. A few are self-taught through prior learning experiences, others can be developed from watching others learn and lastly some may have been learned specifically to aid the student's learning ability. A student's ability to use these learning skills and strategies defines their aptitude to learning. Even though students can assimilate learning skills they do not necessarily understand how to make use of them effectively. Learning these skills has the same problem as learning any other topic.

There are several techniques which student's can learn actively or passively to improve their aptitude. Laurillard[19] describes these as *mathemagenic activities* (p 48), a word first coined by Rothkopf meaning 'give birth to knowledge'[20] (p 193)[8] (p 231). For example, activities such as answering adjunct questions, note taking, and concentrating are used by learners to assist them to study.

Insightful learning — When a student finds holes in their understanding they may reorganise information in order to close these gaps. This can also be carried out for the student by the teacher. By breaking material into significant parts and then looking at the overview of how these parts fit together, a student will find the parts easier to digest. Laurillard[19] suggests the structures can be readily apprehended. Kommers, Jonassen and Mayes[10] believe that parts might also be networked or mapped so that possible new relations can be found. The benefit of reorganising information arises from the reinforcement of insightful learning as the parts suddenly form the whole. The Gestalt psychologists'[43,44] Law of Pragnanz suggests that the organisation of a pattern has a dramatic effect on perceptual learning[7].

Generative learning — When students are actively engaged in learning from essentially static information (books, lectures or other presentations) they are generating their own relations between ideas. Note taking, underlining and summarising the material are methods of focusing attention on the material[20] (p 192). It is often the case that the student will only note down and recall the most salient features of the presentation[45]. However, the student is able to shift this learning strategy once a 'ceiling' of understanding has been reached. Thereafter, a more in-depth level of recall and note-taking is prominent. The ability to communicate ideas requires the skill of discriminating between relevant and irrelevant material, as well as understanding it in the first place.

Active Learning — Not only do learners have to organise information but they must also process that information in new ways in order to extend what they already know. Being able to apply known procedures to situations out of their original learning context is an important skill for problem solving.

Schematic learning is a method which is promoted by Skemp[46] as an aid to active learning. It intervenes the space between prior knowledge and new learning. By carefully examining and defining an elementary schema (or analogy) the teacher can develop a path from some familiar framework to an unfamiliar framework. The use of prior schema and symbols develops *learning sets* of generalised understanding so that later learning can benefit[7]. For example, trying to understand calculus without an understanding of algebra would be impossible.

Historically, discovery learning has never been accepted as a reliable form of active learning[47]. Yet, it is becoming an important consideration with recent technological advances into multimedia. Discovery learning requires both induction and trial-and-error on behalf of the learner. It effectively enables insightful learning at its extreme. The learner is not breaking the material into parts to be easily digested. They already exist in parts and the student is trying to put together the whole picture. Unfortunately there is confusion as to what is the actual outcome of discovery learning. Does it teach how to discover and learn from that discovery (a procedure for learning) or is it a technique for reaching some discovery (the facts themselves)? Both have advantages, mainly that in future the student will have better problem solving skills, will not accept propositions at first hand, and will be more intrinsically motivated due to their successful experience of discovering on their own[7,20]. Unfortunately discovery requires that the student must organise and assimilate information before it is ingested in some form. Other, more passive learning styles, such as mere verbal instruction (lectures) have already organised the information into a form which is easier to absorb. The critics of discovery learning use the positive aspects of passive learning in their arguments. They suggest that the information for discovery learning must be carefully structured to the requirements of the lesson to be beneficial; however, the findings were taken from students who were already practised at passive instruction[48]. In its pure free form, discovery learning does seem both good and bad. The activity of learning is extremely useful and future learning will be better equipped strategically. But the outcome of a lesson may not be what the teacher wanted: knowledge may go uncovered and important points and associations may be missed. However, guidance may be the solution to this problem. Guided discovery involves a more active role for the teacher who will decide the ultimate destinations of the lesson but is willing to allow students to divert (thus modify the lesson) *en route*. Hence only giving the students an impression of discovery and control. The basis of most computer assised learning (CAL) studies in discovery learning, assumes that: a) the learner knows what is best to learn at a given time, and b) the learner is able to act accordingly when wanting to learn[49].

Adversities to learning — Keeping up the motivation in the face of adverse situations can seem to oppose student activity. However these problems are not always de-motivating. Carroll[50] suggested that the problems that arise during the learning of a new computer application are synonymous with typical problems that appear in adventure games. These are disorientation, illusiveness, emptiness, mystery messages, slipperiness, side effects, paradox and *laissez-faire* (no guidance). However if an adventure game did not have these obstacles then there would be no enjoyment and no motivation to play. What makes an obstacle into a challenge is the important point. How the student tackles a problem is dependent on the learning environment. The environment must be able to motivate the student towards actively solving the problem that they are bound to encounter. The remedial actions that are taken by designers of applications attempt to make use of the person's common sense, or just let the user make errors and account for them. Learning during an adventure occurs as the user explores. However the user is willing to wrestle with the adventure to learn as much as possible in order to solve it. Carroll attributes this to the user being motivated and in total control. In characterising an exploratory environment the following ideas were presented (in a non-exhaustive list): responsiveness to every action, benchmarks to relate to other's and own goals, acceptable uncertainty maintains curiosity without creating obstacles, safe conduct so that costly mistakes do not spoil the user's enjoyment ('autolectic' principle)[51], learning by doing (you know it is safe to do so), opportunity to be able to do something even if it is totally unrelated to your goals (productive principle)[51], taking charge of the situation when the user is in trouble, and control must be seen to come entirely from the user, even if it is not.

2.2.3 After Learning

After all the hard work of the learning process, has the student achieved the desired outcomes? These reflections on what has been achieved will mould future lessons and approaches to learning. The goals may have been reached and the needs satisfied but they must be observed by the student. In this case the student will have learned, either consciously or instinctively how to reduce the need that was once so urgent. Assessment of the outcome is an important aspect of learning. Feedback and reinforcement in the conditioning process enables the student to realise which activities provided the correct feedback. However, too often the feedback is solely in the form of rewards and punishment, thus encouraging surface learning.

Assessment

Biggs'[34] Structure of the Observed Learning Outcome (SOLO) assesses at five levels the complexity of understanding. At one end of the spectrum there is pre-structural understanding and at the other there is the extended abstract. Either the student has formed no structure or meaning to the information and completely missed the point, or the student has made observations and abstractions that surpass that for which the original need required. When the learning hits the target the hope is that the student will have achieved one of three outcomes in rising order of complexity: uni-structural, multi-structural, or relational. A **quantitative** transition occurs as the student goes from knowing only a few relevant concepts to knowing a greater number of concepts. As students begin to relate and integrate the concepts, they make a **qualitative** transition. When the student reaches the relational level, learning is complete. The student is deemed able to structure and relate the information with many prior experiences and can utilize it in the future.

The most definite outcome for all students in a particular educational establishment must be the *institutional* product. The results of assessment and examination provide a concrete method of defining the student's outcome. However this outcome can often be too late for reconciliation. Feedback of results must come quickly for it to be useful both for the student and for the teacher in providing confidence, relevance and reinforcement to concepts.

Attribution

Regardless of whether success or failure has been the result of an assessment, the student will try to blame something or someone for it. Attribution theory[7,52] plays an important part for students in assessing the outcome of an experience and deciding whether they are satisfied it met their goal.

The perception of future tasks that are similar to a current task will be affected by how the current task's success or failure is attributed. This is known as *causal perception* and it is dependent on the locus of control[24] and the stability associated with the attribute. Four attributions exist: task difficulty, luck, ability and effort (figure 2.4 from Child[7], p 52).

	Locus of control	
	External	*Internal*
Stable	Task difficulty	Ability
Unstable	Luck	Effort

Figure 2.4: Attributions of success and failure

Task difficulty and ability are stable *causes* of success or failure, and a student will believe that in future there is not much that they can do to alter the outcome. If the cause is unstable then the student will try harder or have better luck next time. In relation to achievement, internal attributions (ability and effort) are the cause of success and failure for high-end achievers, and external attributions (task difficulty and luck) for low-end achievers.

It can be noted that whilst examination results of surface and deep approaches to learning can be good, the extrinsically motivated surface learners can feel bored, alienated and anxious. Whereas, the more intrinsically motivated deep learners feel satisfied, challenged and fulfilled. The *affective* outcome will go on to reinforce the students' future approaches to learning. The student will take this reinforcement into the next lesson as their characteristic presage.

2.2.4 Implications of Learning and Motivation for Instruction

This section described a simple model of learning which an instructive environment might provide for learner motivation. To recap, learning is cyclic in nature in the sense that previous experiences will affect how something is learned and in turn that experience will affect the next piece of learning. Students build on previous learning[7,20]. A similar cycle occurs when needs motivate action in order to gain satisfaction. The method of satisfying that need is learned and motivates behaviour in the future. It can be concluded that the teacher's job is to provide the student with the more complex need — "to learn what is being taught". How motivated they will be depends on their past experiences and the ability of the teacher to stimulate the student.

Definitely a student performs best when motivated and so it is important for educators to understand which techniques evoke motivated behaviour from their students. Rewards and punishment have been traditional ways of motivating people to adopt good working practices but only when applied with care. In tertiary education, a student's motivation can be enhanced by providing desirable and relevant goals which can be confidently satisfied[40,53]. This follows a cognitive psychologists viewpoint to education which studies the intrinsic motivators and the attributions people give to success and failure.

The key issue to teaching and hence learning is the ability to generate satisfactory motivators and needs that can be fulfilled by students. In education, satisfactory needs are psychological, either to relieve some hedonistic desires or to experience self-gratification. In knowing how these needs arise and are manipulated, the teacher will find it invaluable in planning goals and assessing outcomes. The teachers will be able to maintain the motivation of students throughout a lesson. Thus the planning and support requires examining further.

2.3 Teaching Methods

So far the learning process has been described in terms of the needs, desires and aspirations of the learner. The learning process is not devoid of teachers and they play an extremely important role in focusing the direction of learning. Instruction exists to guide a student towards good learning methods and thinking strategies. It aims to support the educational process suggested so far in this chapter. Ultimately a computerised tutoring system must also support learning.

Two areas of instruction are acknowledged to support learning[20]: firstly, where the tutoring material is static and the learner is passive such as with books, references and prose, and the second is dynamic and active, such as a tutorial class or a laboratory session. With passive and static processes, instructors aim to generate course material to suit a wide range of students. Whereas, the problem class is designed to aid clarification, elaboration, consolidation and confirmation[54] of that passively delivered knowledge so that it can be used without error in the future. Experience builds confidence and the ability to make decisions. The design of these two types of instructional material will have very different priorities and guidelines. Furthermore, the environments within which the material is presented must be defined for the intended audience. The environments depend mostly upon who is in control and guiding the education; either the student or the teacher.

These two types of instructional method can be supported best if their design stems from good learning strategies. Laurillard[19] identifies four areas of literature which attempt to contribute to the construction of principles for teaching using a computer (pp 72). These are: i) instructional design, ii) intelligent tutoring systems design, iii) instructional psychology and iv) phenomenography. In her study, she investigates the nature of the empirical base for each area and the nature of the link from that base. This link is made from the base to the required principles of instruction. Her study concludes that a phenomenographic method has the most fitting approach because it considers equally both the students' and teachers' needs. The phenomenographic evidence suggests that two links can be found from research findings to implications for teaching.

> *"1. from descriptions of the internal structures of different conceptions, deduce how teachers and students should make their conceptions explicit so that they can be compared and contrasted.*
>
> *"2. from descriptions of the differences between successful and unsuccessful teaching, deduce the characteristics of successful teacher-student interactions."*
>
> [19] (p 83)

In summary Laurillard makes the statement that teaching strategies should be based upon the dialogue between student and teacher. This dialogue consists of descriptions of actions in the world. The following characteristics of education are necessary to support the learning process (p 94):

Discursive	• teacher's and student's conceptions should each be accessible to the other; • teachers and students must agree learning goals for the topic, and task goals; • the teacher must provide an environment within which students can act on, generate and receive feedback on descriptions appropriate to the topic goal;
Adaptive	• teachers have the responsibility to use the relationship between their own and the students' conceptions to determine the focus of the continuing dialogue;
Interactive	• the students must act to achieve the task goal; • the teacher must provide meaningful intrinsic feedback on the actions that relate to the nature of the task goal;
Reflective	• the teacher must support the process in which students link the feedback on their actions to the topic goal for every level of description within the topic structure.

These characteristics are similar to many of the guidelines which have gone before but differ in the way they treat the learning process. Previous guidelines have suggested methods of improving teaching strategies albeit by taking note of learning theories. These previous guidelines provide teachers with actions to carry out on the student whereas Laurillard's guidelines promote interactions between teacher and student.

As expected these guidelines relate to the cycle which motivates people to fulfill their needs and learn new material. However, the complexity of the tasks to be satisfied in learning environments means that the teacher's job is not a simple matter. The instructional model requires the teacher to utilize the student's need to satisfy desires in order to motivate them into action[20,55]. Thus, the three stages of instruction and learning enable the teacher to:

1. plan the lesson so that it creates a need to be satisfied;

2. maintain the students' motivation by increasing their expectancy that the need will be fulfilled; and finally

3. assess what has been achieved, that the need has been reduced, and thus strengthen future learning.

2.3.1 Environment for Instruction

In an environment over which the teacher has complete control, what is told to the student and what they should have access to will depend upon a pre-defined plan. The actual existence of the student does not matter and the lesson will progress according to the plan. Often the teacher will adopt a strategy that involves drill-and-practice, tutorials or just straight forward exposition of knowledge (classic lecturing). The advantage of this style of teaching is that it enables fast acquisition of new knowledge rather than review or assimilation of old. Prior knowledge is not usually an issue[49], although at the lesson level, introductions and conclusions will be necessary. The student might be considered to be a vessel into which teachers can pour their knowledge. Of course, this knowledge must be structured to pave the way for future learning. For example, some rote learning tasks such as the application of mathematics, the alphabet or chemical names will assist a student to work more efficiently later but require only surface understanding. Algorithmic problems that are set by a teacher make use of this knowledge. The student will be able to follow a set of rules or operational steps in order to get to a solution.

In contrast, a teacher will have very little control over exactly what is learned in a student centred environment. The teacher can influence the learning through instructing the student how to learn and assess themselves. The teacher can also indirectly affect what is presented to the student through information sources, such as books and other media. Strategic problems seem to require and enhance deep understanding in comparison with algorithmic problems. Algorithmic solutions require planning and fore-thought by the student, the correct outcome is never assured and can remain undefined. These are often more challenging, but without support these challenges can become obstacles to the student's progress.

It is important then that a teaching strategy (either centred on the teacher, on the student or a mix) matches the goal-action-feedback cycle. The teacher must set tasks which the student can reasonably achieve. The tasks should be adaptable to the ability of the student or take into account the varying degrees of expertise. As stated earlier, students have entry predispositions which affect the way they approach learning. Teachers can only hope to ascertain or preclude what these are by 'knowing their audience.' The teacher might suggest aspirations or intentions to improve the student's approach to learning. Opportunities must exist for the students to work actively towards finding a solution to tasks and teachers should be available to provide support for building confidence. The teacher should not solve the task for the student but encourage good work appropriately, the student can then attribute the success intrinsically.

By having a variety of environments that are heavily orientated towards who is in control, it is possible to lay the foundations for the application of teaching strategies for motivating learning. Again the teacher is trying to maintain the students' needs to know more about a topic and this can be done by exercising their intrinsic motivation. Whichever environment is used, motivation can be maintained through good instructional design.

Along these lines, Keller[55] identifies four basic strategies for ensuring motivation of students through instructional design. The ARCS concept requires that the teacher:

- focuses the student's **A**ttention,
- **R**elates the content of the course to the learner's past experience,
- builds the **C**onfidence in the student by gradually increasing the difficulty level to be challenging yet achievable, and

- ensures that enough positive feedback and reinforcement is given to **S**atisfy the student's aspirations.

2.3.2 Instructional Design

The teacher's job is to ensure that the most fitting approach taken is that which is appropriate for the task and which enhances the experience of learning. This requires a design of instruction that is going to help the students maintain their interest and to focus their attention[53,55].

Earlier in this chapter it was made apparent that a student has preconceptions to learning and a process of learning. The *content* of learning and the *context* affect the student's initial approaches to and eventual outcomes of learning. Content is the material and presentation style of a course, whereas context is the actual cognitive setting of the learning. Laurillard (in the introduction to generating a teaching strategy)[19] states that the context bares little relation to the problems set, and that the context is often decoupled from the description of learning. Very little research has been done in this area. Nevertheless, Mayer[20] states (in the conclusion of instruction for thinking strategies) that the learning context does affect how problem-solving expertise is remembered.

Optimally, the teacher wants to create content for motivated learning but in the light of the students' own ideas, preconceptions and misconceptions, their interests and individual experiences, and their own approaches to learning, i.e. the context. Before a lesson even begins the teacher must be sure that: the content, structure, methods of teaching, time and schedule of learning, and possible sources of stress for the student have been considered[34]. The teacher is trying to create unnatural needs that are relevant for the student and build confidence in the student's ability to satisfy the reduction of those needs. A good presentation that has been well prepared will motivate, captivate, and stimulate learning. In some ways teachers are actors in front of a generally unresponsive audience[56]. They must write, direct and produce their own performance.

The teacher must decide upon what tactic to use for providing the best form of instruction[20]. Accordingly the course subject helps the teacher to decide upon a direction for the lesson. If the task is to learn some new information then full tuitional control is required to ensure that a correct correlation of facts is acquired. If the information is easily accessible and the student has some structural knowledge of the domain then little control is required by the teacher.

Maintaining the interest of students is difficult and requires re-iterating the expectancy that the students have of their actions resulting in the desired outcome. The need will often wane because of external problems that are bound to arise. Traditionally the need to achieve has been equated with the need to pass assessments and avoid punishment. Modifying the behaviour of students using extrinsic rewards and punishments has very short term effects. Techniques which have long term promise require the teacher to maintain an environment which will enable the student to complete their goals successfully even in the face of adverse situations.

2.3.3 Implications for Educational Design

When learning takes place the emphasis is on the controller of the environment to encourage motivation and assess satisfaction. In teacher controlled environments the teacher can utilize good teaching practices. When the student is in control they must use good learning strategies for self assessment[20,57,58]. Brophy's[8] list of motivational strategies (pp 410-438) suggests that students' learning outcomes are affected by a lack in their effective use by teachers. CAL designs have relied on assumptions about the learner knowing what is best to learn at a given time and being able to act accordingly[49]. In education, it is easy to fall back on teacher controlled environments because assessment of the work and further planning is much simpler. Support for teaching the art of student self-assessment, and acquiring feedback from it, is often very vague[57].

The instructional design must allow the student to become cognitively involved. That is, it should support need creation and fulfilment. However, to generate intrinsic needs often requires the learner to receive individualised tuition.

This is because students will learn better from a discursive dialogue between the teacher and student. It is important for this dialogue to be maintained.

2.4 Conclusion

In summary, motivation has been seen to support the theory of learning and suggests that in order for people to learn, they require goals, actions and feedback. These stages relate to the 3P's model of learning and this is cyclic. A student has a presage, process and product which must be present in order to learn. Furthermore, all of these lead towards activities which allow a student to reflect upon what they have learned actively. In the conclusion to Mayer's chapter on instruction for thinking strategies[20], he points out that systematic areas of research have discovered conditions that assist problem solving training. Firstly, most effective learning occurs when "the material to be taught consists of specific, individual problem-solving skills." Secondly, "students also profit from generating and analysing worked-out examples and comparing their own solution processes to those of experts" and lastly "students tend to learn specific skills that can be applied mainly in the same kinds of contexts as the examples used during instruction." (p 239) The implications for reflective learning are that the discussions during learning should be directly related to what is to be taught.

In order to support reflection the teacher is required to generate prose and tutorials. The goals, actions and feedback must be generated to support the strategies and techniques which students might use to learn. In order to do this teachers require supportive guidelines. Some principles for the design of instructional material have come from phenomenographic studies. These studies suggest that discursive, adaptive, interactive and relevant characteristics are important. Mostly these are teacher generated but require and encourage student engagement in an educational dialogue. Teachers will generate prose and tutorials whereas students must develop memory and thinking abilities.

During teaching, the structure, sequencing and reinforcement of knowledge all play a part in creating a motivating environment. Correct delivery of that knowledge can make it dialogue based. A conclusion for a computer-based technique for teaching and learning requires the dialogue to be planned prior to student interaction or to automate the discussion as the student interacts. Teachers are therefore supported by a computer system if it assists the creation of prose and tutorials. This is goal creation. Students can be assisted if memory and thinking abilities are also supported. This is action enablement. Both should be communicative so that an attentive discourse will ensue and so that the material will remain relevant. Similarly their integration should make students confident in their abilities and furthermore satisfy their own needs.

Chapter 3

Hand-Crafting Educational Information Technology

Representing information digitally for educational purposes presents a number of problems for both the author and reader but the benefits are potentially enormous[19,59]. This chapter will investigate methods that have been proposed for creating a reservoir of knowledge on a computer as well as methods for subsequently draining this reservoir at a later date in the form originally intended by the author. It will introduce the conjunction between educationalist research and the adaptation and adoption of computer technology. Educationalist research has suggested that principles for teaching play an important role in the development of good courseware. An effective dialogue between the teacher and student promotes good learning outcomes.

In general, IT systems have been used in 2 ways for education: i) as test vehicles for specific educational strategies in order to discover the benefits that they possess for the student, and ii) at a practical level, they provide the tools which assist the teacher in providing resources for students. The former view is explored in detail by many researchers to improve learning outcomes by utilising CBE. The latter assesses the learning outcomes in order to evaluate the effectiveness of teaching tools. This chapter focuses upon the author's impact on learning outcomes by using tools.

Requirements of CBE implementations

It is primarily the end users which have to be satisfied by CBE. The satisfaction of students comes from the information which the teacher can provide at the correct time throughout the different phases of learning. The information which will be delivered depends upon what the student is asking of the teacher. In theory, it is the ability for these two end users of the educational process to communicate with each other effectively which will result in improved learning outcomes.

Ensuring a mixed initiative of control between teacher and student is extremely valuable. This means ensuring that the information content of education is neither solely **static and active** nor **dynamic and passive.** Static and active in the sense that the material **does not** change but the student is intended to think about it. Dynamic and passive in the sense that the material **does** change to student activities but it is not requiring the student to think. In a mixed initiative setting the tutor or courseware can be either dynamic or static, and the learner can be either active or passive.

It can be dangerous not to mix initiatives. The student is often willing to take a passive role in the learning, taking what is given and hence learning only what is needed. Similarly the lecturer may also want to take a passive role and not expect to have to interact with the students in order to provide supplementary knowledge (Figure 3.1).

Active and Inquisitive Student	+	Active and Vocal Tutor	=	Very Good Learning Outcomes
Passive and Reticent Student	+	Passive and Introvert Tutor	=	Very Bad Learning Outcomes

Figure 3.1: Problem of mixed initiative

The best form of learning is achieved when the student and teacher (or other students) are working in collaboration in order to come to a solution[60]. This form of group learning extends from the one-on-one individualised tuition to the peer tutoring that occurs in many educational situations. It is most recently that computer systems have been driven by good teaching practices and cognitive learning strategies with the aim of providing surrogate methods for interactive learning[10].

Over the past 30 years CBE has been divided into several streams of research and development ranging from the imperatively programmed machine, through intelligent tutoring systems to increasingly interactive and media-rich systems. However this development has arisen through changes in information technology more often than the advances of educational research or changes in educational requirements. For instance, technology allows communication to occur across great distances.

Students gain advice from their teachers by entering into a tutorial dialogue. The main requirement of CBE implementations is to satisfy this tutorial role autonomously. In general, this is achieved with systems that stem from programmed instruction, simulations and ITS. Essentially, these systems give the students access to the teacher's understanding but in response to their direct activities. The information is to supplement knowledge which the students already have in order to help them progress in their understanding.

3.1 Authored Tuition

Primarily, systems are designed around the available technology rather than education or end-user requirements. Obviously future hardware cannot possibly be known in advance. However the mere existence of a new technology must not be taken as an excuse for its adoption. Initially computers were used for numerical calculations but the power to store textual information soon led to more imaginative uses. Not only could data be stored and transmitted, it could be searched and modified according to pre-programmed rules. The rules could associate, thread and conditionally reveal information based upon user inputs. These inputs could easily provide search criteria to the software accessing a database. The drive towards using computers in education came from the realization that an electronic machine could be used to relieve many mundane teaching tasks. The aim was to write software that would help instruct students efficiently and with the same quality of learning outcomes each time. An aim that is still to be fulfilled.

3.1.1 Authoring Languages and Applications

The power to automate the delivery of instructional material has excited many educationalists. *Programmed instruction* was considered a way forward for education since it would ensure the same education every time[61,62]. The initial means of making a computer teach was to computerise programmed instruction in a typical computer language such as FORTRAN. The teaching material designed by a teacher such as a physicist or chemist would be developed into a usable piece of software by a computer programmer. The resulting application would then be maintained by either the originator or another professional programmer[17,62]. The programs themselves were of 3 main types; linear, branching and generative, which are all still found in current applications[63].

It is more efficient for the teachers to not rely on programmers but to encode their courses directly. This means allowing the authors to produce the programs themselves. If the teacher produces the program, less time is spent communicating the design to a programmer. Yet teachers are not programmers, thus it is necessary to create authoring tools that can be easily used by teachers. Furthermore, any misunderstanding that the teachers have of the computing media will mean that ineffective uses of the machine will be made.

- **Ways of easing authoring**

An attempt at making it simpler for a teacher to create a course is to simplify the teaching method. One method is to adopt the 'cloze procedure' or 'filling in the spaces' approach[8]. The teacher simply writes a sentence and selects some words to be omitted. These words are then given as a list to the student who must find where they fit into the sentences[64]. A high teacher involvement is still required to develop the student's ability in the right direction, and to promote student-centred writing ability.

Similarly, multiple-choice questions are a form of tuition which can be relatively easily programmed by a teacher. They require the student to read and understand the question before giving an answer, and the computer compares it with the model answer. Unfortunately there is the possibility that students will guess and not really consider the answer. Only if the computer records the interactions or attempts at a question, and then sends the results to the teacher might students reconsider their guessing strategy.

Rather than simplify the teaching strategy, the encoding mechanism could be improved. Specific educationally-orientated programming languages were the first IT assistance given to teachers who wanted to code their own strategies for instruction. The most prominent of these languages (largely due to its vast functionality and the amount of time and money put into its development) was PLATO[11]. But it was more than just a language; it was an all-encompassing authoring system. The PLATO (Programmed Logic for Automated Teaching Operations) development started in the late 1950's and the first design was completed in June 1960 by Donald Bitzer at the University of Illinois in conjunction with NovaNET communications[11].

Improving the way in which teachers can provide advanced programming might require the adoption of operating system methodologies. A distributed multimedia O.S. is the technique employed by the project NESTOR[14,65,66]. Its purpose is to make very wide-area networking more efficient and accessible. NESTOR emphasizes the science of instructional design and provides an educational environment on the computer.

The top layer of NESTOR supports authoring and learning. Specific tools can be *customized* by the author in many ways and the authoring/learning can be aided by employing *processes* or models. The processes are used to define instructional strategies, learner models and transactions (dialogues between the system and the student).

The major contribution of the educational O.S. is that as the material becomes more structured in the CBE system, the content becomes more distinct from the surrounding program code which presents it. Framing the material like this means that other technological packages can be adopted and the result of the work imported to the educational system. By utilising a frame-based architecture[67,68,69] the interactive delivery of publishable quality material can be supported. Thus an improvement in teaching can be gained by encouraging the organisation of material for presentation in such a way that students reading it will be able to absorb it at their own speed. Naturally, the prose developed by the teacher must be well written so that a student reading it can effectively understand the descriptions (chapter 6 [20]).

Now that content and presentation are separate from the courseware framework, authoring often involves graphic design. For example, desk-top publishing packages (DTP) have been used to generate some aesthetically pleasing material. Yet, these packages rely upon the user having a knowledge of artistic methods just as much as most computer-language compilers require the understanding of some basic programming principles.

Once the content is produced the interactive framework must be developed. EULE[70] is a tool for education which stems from AUTOOL[71] and HyperCOSTOC[72]. It is a system based upon an object orientated paradigm. EULE (German for owl and hence wisdom) is divided into two sections, called EULE-A and EULE-L (or EULE-Tutor) for authoring and learning. The learning material can be organised into books (like a course textbook) and laboratories (where problem solving is carried out). The books represent the lessons which are generated through a net-like structure where every node can be linked with every other node. The nodes can represent text, graphics and points of interaction. Authoring involves the creation of models which can be 'reused' and 'adapted' thus progressively making the processes interactively simpler. The innovation of EULE is exalted as 'flexible adaptation.'

It has been seen that a variety of methods of interaction have been implemented to assist courseware construction. Mainly these have attempted to simplify the organisation of material for the lecturer into parts and enabled these components to be created independently. The components can then be composed using various rules and associations that provide a program for useful tutoring. To generate these rules and components more systems opt for a windows-based solution that allow the user to directly manipulate representations of the associations, text, pictures and so on[73,74]. This benefits the visualisation of the course interactivity but as more complicated networks and programs are composed, so this visualisation breaks down. Nevertheless, directly manipulating information on a display has overcome the problems found in mnemonically-programming the relationships. Unfortunately, direct manipulation often still requires a technical understanding of programming principles.

3.1.2 Hypermedia Applications

With recent developments in processor speed and video compression software, it has become increasingly viable to incorporate multiple media into educational courseware. The integration and association of these media into hypernetworks has renewed interest in constructivist learning[10]. Furthermore, because students will have been taught via more than one sense they will be able to draw upon the information contained in these media more easily in the future[16,20]. A step towards using hypermedia (and concept networks) as a teaching and learning method was developed by Huber, Makedon & Maurer[72]. Their HyperCOSTOC system extended an earlier system called COSTOC (Computer Supported Teaching of Computer Science). Its approach is again hardware-independent and is able to integrate with various types of instructional environments (for example, another CAL application). It has much in common with educational O.S.s but with support for hyperlinks.

Many hypermedia courses are generated by authoring links between material which can cause a number of problems[75]. These occur at several levels and will all impede the student's ability to learn. Many mistakes can easily be made. For example, wrong branches, wrong lesson structure, inconsistent naming, inconsistent layout of frames, lessons too long, inappropriate number of chapters, inconsistent layout of chapters, all have been named as making a lesson unsuitable. Many more problems are identified at other levels and systems which attempt to enable authors to produce good courseware should be aware of these problems. For instance, the HyperCOSTOC author can develop a hyper-network using the routing editor. The nodes of the hyper-network are called HyperMols (or just *mols*) in HyperCOSTOC and these are the individual unit concepts that a teacher may want to present. Links between mols are added and deleted with the routing editor. The stability or integrity of the routing is checked for certain anomalies that can occur after links have been deleted. A commercial system called Authorware[67] also uses a simple mechanism that follows a flowchart style routing editor. The links are unidirectional but they can be looped and branched. The confusion which might have been caused by a hypermol web is avoided by using a visual and sequential form of programming.

Intermedia [74] attempts to manage the integration of high volumes of multimedia. It is an author's and a reader's tool which can be used to build and browse hypermedia networks. It uses an object orientated approach to build the network. The user is presented with a variety of object classes - selection boxes, view windows, command levels and dialogues that can be manipulated. This provides a great deal of functionality and versatility. However it does not address any of the specific requirements of CBE in the sense that it is only partially aimed as a medium for learning. It is entirely at the discretion of the author as to how the information is presented.

In implementing multimedia the student is given access to browseable databases in the form of an interactive encyclopedia. These systems have no feedback as such because they do not allow for instructive queries to be made of the content. Searching is often all that is facilitated, although navigational tools for hypermedia aim to take this "beyond a mere search for information"[76].

The student can browse a HyperCOSTOC web in much the same way as browsing a world-wide-web. The student follows an H-Tour by opening windows onto mols. During their tour the students have facilities to attach notes and annotations to the mols which can also be marked as either public or private. The annotations can be *enabled*, thus allowing selected annotations to be made public by the user, or *active*, allowing any annotations to be linked to pieces of material.

Navigational tools enable information to be gathered for later perusal - a sort of 'annotated/recorded' browsing. To improve the search facilities, built-in rules can be defined to control the breadth of information returned in answer to queries. Even though the information is presented on-a-plate, the act of searching will give the student a sense of control over their own learning. It will also require them to think about their querying actively[77,78]. This kind of searching may be classed as discovery learning but the technology must be used well to avoid the mechanism being just an extensive library catalogue. For learning, guidance should be incorporated subtly into the searching system to press the student toward requisite knowledge.

Although systems such as NESTOR[65] allow content information to be ideally created it is still passive material and only adapts to students' inputs very superficially. An improvement is to use technology to automate both the selection of material to show students and then provide instructive feedback to their educational queries. When delivering instruction, the computer can control what is shown to the student. Normally the teacher has programmed that control in a rather simplistic manner, or the student is requesting information that they might require. Furthermore, with traditional course delivery the computer responses must be in a range anticipated by the author. The author is organising information for a particular audience. Hypermedia construction needs information to be well-organised by the teacher. These responses cannot be adapted by the computer that has been interacting over a long period with a particular student. Fortunately, it is possible to program the computer so that it has more flexible control over its own output. To do this the system must have some form of artificial intelligence. It organises information for the student according to built-in rules. This is described in section 3.1.6.

3.1.3 Facilitating Educational Theories

To meet educational values, techniques are generated or adopted from educational theories to fulfill the teachers' needs in tutoring students. The simplest activities for which a teacher can provide are question and answer sessions, perhaps with examples encoded along the way. Simple information delivery involves presentation techniques which a teacher can adopt to pass information quickly to the students. This, as in many of the early computer systems for education, will generally ensure good retention and recollection of information.

Methods of teaching which are adopted to make the retention of information easier generally chunk information into usable parts[20]. By working through all the parts, the student will eventually understand the whole. This can be done quite easily using many current computer tools. TICCIT[11] attempted to use this as a primary technique and additionally gave the student the option of working through different parts as that student saw fit. TICCIT decomposed courseware into rule, example and practice parts and the order with which the student accessed these was not fixed.

Another method which was adopted early was to provide material which supported rote and schematic tutoring[46]. The information is constantly presented until understood or the material is varied with the use of analogies and alternative representations of the actual knowledge. Again the programming of a computer to present the same or varieties of information is simple. Unfortunately the teacher must author these alternative descriptions. The method relies on the student eventually understanding because it has been reviewed so many times or because one of the different representations makes sense.

By emulating traditional methods some attempts have been made to place lectures onto a computer. This normally involves the presentation of material in similar ways to live lecturing - for example, with animated overhead projector slides[79]. The benefit of having these is to make the motivation for learning and orientation of the student more exact. It consolidates and confirms knowledge for the student in a pre-packed form. However only limited learning gains can be made without a real lecturer present. This could be due to a lack of direct feedback[19]. This kind of material however can be very easy to create once the tools have been learned.

Advice during learning involves the existence of a digital assistant. In this case the computer is acting as a silent partner in the process of using another computer-based system. For example, during the first few hours of using a word processor a small help window may be constantly on the screen. In this window the most common first actions are displayed such as 'Start a New Document', 'Typing', or 'How to Quit'. As the user learns to carry out these initial steps the menu will change with respect to what they are currently doing and the most likely next choices. This kind of assistance is usually designed for a specific computer application (e.g. Macintosh help bubbles and Windows 95 tool-tips) but similar systems exist for actual academic learning[67].

The SCHOLAR system which was studied by Collins *et al.*[80] attempted to be the first step towards CBT that acted like a real teacher[62]. That is, communicating with students with respect to known facts rather than reciting sets of prepared questions. In SCHOLAR the data is changed rather than the program. The data represents a semantic network which allows the program to make up relevant questions and search for answers to questions posed of it. The premise is that students will ask questions as they arise during normal working. However, SCHOLAR uses a terse and repetitive form of English for the dialogue and it cannot develop or modify a plan of action.

3.1.4 Problem Solving

Problem solving involves the student actively working with a specific question or hypothesis in order to find its solution. This question presents the student with a goal. The computer implementation of the problem solving technique has always given the student opportunity to experience the process of "coming to know."[19] This activity may be accompanied by guidance material. Implementations, which may be hand-crafted, come in the form of simulations, microworlds and problem classes.

Simulated environments attempt to overcome the restrictive dialogues offered by rigid exercises and allow the student to experience theories in practice (e.g. Newtonian physics). The simulated environment enables a student to find solutions to preconceived ideal problems in their own time. They can also remove the dangerous, repetitious, costly and time-consuming aspects of real experiments in addition to being a medium for discovery learning. The student can gain experience of real phenomena and form their own conceptual ideas about the properties which they simulate. A consequence of the pure simulation is that the ideas and conceptions which a student forms can be incorrect. Trying to rectify this misconceived theory later would be extremely difficult. Once a misconception has been made the correct knowledge has to be relearned more effectively in order to supersede the old.

LOGO[81] is an implementation of discovery learning that has been examined extensively[20], (pp. 156) as it is claimed that learning LOGO will assist in other problem solving areas. Unfortunately there is little evidence to show that 'pure' discover learning via a computer which can give immediate feedback is effective. In LOGO the pupil is given access to the LOGO programming environment and is told some of the language syntax. They are allowed to experiment and discover at will and are given little exercises (draw a square, draw a triangle) which they can complete through experimentation. The pupils learned after many hours of use how to use LOGO for solving these tasks procedurally including writing sub-programs. Error messages from the LOGO interpreter give the pupils an idea of their ability to program. However they were unable to transfer what they had learned to a more fundamental understanding of programming. For example they could predict the outcome of certain small programs but had developed incorrect conceptions of how programs operate. It is valuable for a simulator to generate error messages that will advise by suggesting possible solutions to the problem or the first step towards finding a solution.

The feedback in simulations in terms of the teaching process has been ill considered. "For example, feedback was good enough for science but not for learning."[19] (pp 93) The hope that the simulation will enable learning is expecting a great deal. Being able to carry out the activities required in actual work does not necessarily enable the student to learn. An advisory system will only provide practical feedback about the process rather than academic feedback of the reasons.

Implicit advice from simulations will aid and assist conceptual diagnosis and hypothesis testing and not provide the academic summaries required for long term recollection. Nevertheless, the reasons for successful learning will be properly attributed to the student's hard work by the student. Thus initiative is well balanced.

An alternative to the simulation is the microworld. Simulations usually require an understanding of the mathematical model underlying a concept. In order to overcome this, microworlds are used. Microworlds do not accurately model the physical world but present the student with hypothetical situations in an environment where predictable rules are evident. They allow the student to play educational games such as business games. Alternatively the computer can place the student into adventure-like situations for the student to play the role of a character in that adventure. Hyperworlds and virtual worlds[73] can enable a student to gain an understanding of knowledge through visualisation. Yet, even though all of these environments provide the student with an opportunity to gain implicit feedback they can never enter into a traditionally rich dialogue.

To alleviate the difficulties associated with programmed simulations, some problem solving systems like EULE[70] can create typical learning activities. For example YES/NO questions, multi-choice, paring, puzzle, gap-text, free-text and also there is the possibility to create new types of activity, e.g. graphical. In EULE these are placed into its laboratory area which the student has access to for problem solving. Hints can also be created as text elements within the system if the student is having difficulty. How these link to the other elements in EULE is not explained. Problem solving learning is done by analysing results returned from the actual laboratory environment exercise. Depending on the accuracy, a teacher will be able to assess how well the student has understood the material. Because the material was examined in a laboratory environment it seems that the student should be exercising their learning.

3.1.5 Exploration

The static media which is learned through active thought can be generated in many ways. Generally this type of computer media equates to examples, questions and their answers that are given after pre-requisite knowledge. However a recent development has discovered the advantages of constructivism in education[10]. This is where the student develops their own understanding of the world from using resources available. It is similar to the discovery learning which a simulator can facilitate but the information is static. The most common implementation for constructivism is problem solving through hypermedia. Prior to this a very conscientious student could make good use of a library of recommended texts. With CBE, the computer can filter and guide the available resources. Rather than have a rigid structure to education, the use of a variety of different educational resources satisfies specific learning needs. Intermedia and Microcosm make the construction of this courseware easier by allowing varieties of applications and indeed, courseware to be integrated.

It is hypothesised that viewers and listeners will be able to make more mental connections because different kinds of memory are used for remembering different media[16,20]. Yet presenting varieties of media to students in educationally useful manners requires lengthy authoring. A solution is to let the readers browse any professionally created resources themselves. The element still missing is that the different resources do not have any conceptual associations. This means that teachers must build associations between items of information so that students can later follow those relations.

This resource-based learning provides the student with all the material they require to learn on their own. It is suggested that from successfully utilising the available material they will achieve good learning outcomes. This is because they will have made their own discoveries, and they will have generated their own connections between the resources. This is not always the case and it depends a great deal upon the aptitude of the student. The earliest technically viable design for this was suggested by Vannevar Bush and subsequently by Ted Nelson[82]. In addition to simply providing links between material, the material itself can be made to make use of all the senses. Multimedia and its hypertext equivalent, hypermedia, are taken as being an innovative method of teaching. It is considered to be an extension of the mind, enabling technology to "surrogate for our missing picture generating organ"[83]. In this sense it enables the teacher to project their thoughts to the students in a much more visual way. Without information being presented linearly in books we can see it as it really is: an interconnected web of arguments and facts. Hypertext and hypermedia designers advocated this to be much closer to the way in which the mind works and it is the process of rationalizing this web that aids learning. Unfortunately the extra cognitive load required for manipulating the system can be de-motivating when the web is too complex: only small challenges should be used to retain the student's attention. Someone learns by building upon what they already understand.

Using hypertext[73] is supposed to aid learning by solidifying the memory links in the brain and by forming links between the student's current knowledge and new information. However students must be active in their browsing. Hammond[84] names 5 problems with hypermedia in an educational context: users get lost, an overview is difficult to get, specific information can be difficult to find even if it is known to exist, users ramble through material in an unmotivated and inefficient way and finally the interface for exploration can be bad. With more usable hypermedia interfaces this last point is being reduced (for example, Netscape[85]).

The advantages which hypermedia hold for the learner are based on the mind working by associating known and unknown material for learning. In essence the non-linear and a-linear progression through conceptually sound units of knowledge provides a good basis for many known styles of learning (explicit vs. implicit, deep and surface, holistic and serialist). However, some prior knowledge is important and the media must be placed at an appropriate level of instructional control.

3.1.6 Intelligent Tuition

Automatic control of information is attempted within Intelligent Tutoring Systems (ITSs). When a person teaches effectively there are two pieces of expert knowledge which will be used. The teacher's understanding of the course material (domain knowledge) and the teacher's understanding of how to teach the course material (teaching knowledge). The domain knowledge will enable the computer to analyse the correctness of student responses. It is usually made available to the system by a knowledge engineer working with the course expert. The engineer must also capture the teaching knowledge with help from an education expert. This knowledge has to reflect the learning difficulties that the students' responses might indicate and how to deal with them. The ITS must build a model of the student as the student interacts with the system. Intelligent CBE does not try to lead students according to a pre-set plan but directs them in a pseudo-intelligent manner according to rules.

The ITS can effectively give students a teacher of their own so that they receive individualised tuition. However interaction with their artificial teacher in current tutoring systems is rather unnatural and needs improving. Furthermore, implementing an ITS is a lengthy process which requires a specialized understanding of "knowledge-base" development. Its application in all areas of academia is unclear since it has few concrete boundaries and current implementations only provide partial solutions to a small number of topics.

Hence, in summary, for a tutoring system to be intelligent it requires the following knowledge[86] :

- knowledge of the topic to be taught;
- knowledge of the users and their performances;
- knowledge of suitable teaching skills;
- a theory of how to apply those skills in particular cases.

In all cases, the knowledge is extremely topic dependent and difficult to apply in the general case.

Two systems which utilize artificial intelligence (AI) techniques are SOPHIE (I, II & III)[87] and GUIDON for MYCIN[88].

SOPHIE went through three design stages in its intensive attempt to be a complete ITS. Its policy was to encourage students to make hypotheses. The system used intelligent reasoning that employed coaching strategies via an articulate expert trouble-shooter and student modelling. Whereas SOPHIE is an ITS in its own right, GUIDON is a tutoring system built upon MYCIN. MYCIN is a medical expert system which could be used to diagnose ailments from a description of the symptoms[89]. GUIDON was an educational front-end for MYCIN which presented medical students with cases to examine. The system always knew the solution in advance and as with all expert systems had a closed-world model. Only the data stored in the system was "understood" and any other solutions would be ignored.

Of course, the main problem with ITS is that the knowledge base of teaching strategies and topic structures must be authored. A typical system for authoring is TRAS[90]. Novice creation of an ITS system is either difficult or impossible. Some expert authoring knowledge is already required by the teacher to obtain the simplest system of intelligent tutoring. For hand-crafting education, ITS provides no solution simply because of the nature of the information required. However, the concept of representing knowledge may be useful in a restricted dialogue that follows a set of teaching practices.

Intelligent CAL research looks at having systems that can advise the user[91], adapt to the needs of the student, and automatically generate lessons[92]. Since ITS has a model of the student and an understanding of their conceptions it can individualize its tutoring. The benefit of individualised tutoring is that the time spent learning is much less than it would be in the classroom situation. Furthermore the tutoring can select the most appropriate and well researched educational strategy (e.g. adjunct questioning). The effect and success of these strategies will be adapted as they are used in systems.

3.1.7 Summary of Authored Tuition

Technology has been used to develop many environments for education. However, the tools that have been generated seem to satisfy the designers only. They make good and efficient use of the computer technology but do not explain how to make use of computer technology for education. Authors and students are able to make optimum use of the IT tools for improving their individual environments. By disregarding the structure of information, the IT support of the content authoring of courseware is low. The technological possibilities still overshadow the final effectiveness of the course. High quality visuals can put a shine on what might be fundamentally flawed course content.

The main technological development in recent years has been the authoring system. Authoring mechanisms have focused upon improving presentation authoring. Yet, these have seldom considered the actual educational requirements. They have provided lots of functionality which might be seldom used.

For instance, HyperCOSTOC provides a well structured system for course production and facilities for integrating the instructional design with the lecture delivery. The mols are usually small and context independent which can be designed and tested as individual modules. This would suggest that the quality can be maintained and the speed of production can be high. It also attempts to include teaching strategies in the form of libraries and customizable modules. Yet, the effectiveness of these modules at easing the development of courseware is unstated as is the novice usability of the entire system. Nevertheless, there had been over 500 lessons created for the earlier COSTOC system by 1988 but large sections of the HyperCOSTOC system were yet to be implemented. Although the structure of information is valid, it only provides a simplistic view of authoring in terms of the tutoring styles that might be adopted. The main aim of the project has been to incorporate hypermedia into the original COSTOC system and produce tools for authoring. Similarly, Hyper-G has taken this a stage further to incorporate internet hypertext construction.

More important uses of technology are artificially intelligent methods for teaching. Theoretically they seem very promising at emulating the instructor entirely and insist upon a good structure to a course. Functions such as course selection, response evaluation, feedback and modification of instruction can all be controlled by the computer. Yet, due to the amount of time and effort required to encode the knowledge of skills for even the simplest of topics, AI has still to be realized at a practical level. The level of dialogue can still be unnatural and so is not as good as the real teacher.

To gain developments from educational research, CBE often aims to provide students with the necessary resources they require to fulfill the 3 phases of education. This is done by both giving the student control and withholding control when educationally most beneficial. It also aims to promote good learning styles so that future learning is improved. The balance between what a teacher provides and a student finds for themselves is maintained in a variety of ways in CBE. The teacher controls the amount of information by fixing prerequisite knowledge and only testing this. Alternatively they give students the freedom to access a subset of the possible information. Thus the student is actively browsing the information which they require. This information may be static (textual or graphical) for the student to peruse, or it may be dynamic (a simulation or microworld) that allows the student to *play* with the environment.

Simply giving control to a student appears to relax the responsibilities of the teacher. The student will be better prepared to learn for themselves in the future but a teacher must still ensure that the students learn the correct information this time. By guiding the student towards discoveries, the teacher has to confine the student to the realms of necessary information. The systems which allow a student to explore a predefined realm of information are often programmed by the teacher. A number of mechanisms (NESTOR, Intermedia) allow the teacher to create and/or integrate their own courseware. The ideal is to generate a sphere of knowledge which can respond to any misconceptions detected in the student so that corrective feedback can be provided.

3.2 Physical Remoteness

All of the previous methods of ensuring a good level of mixed initiative have tried to emulate an active teacher in the system. This is because the teacher cannot be physically active at the time the student requires assistance. However this temporal remoteness can be satisfied by recording either end-user's activities for the other to view later. The student can work through problem classes which they might have missed and teachers can view the work which one or more students have done. The computer requires no other information about how to teach or support the learning strategies. There is little feedback from this kind of mechanism and the computer processing power is not being fully utilised. In contrast the teacher could be purely physically remote but available in terms of time.

A major advantage of electronic computer networks is the ability to communicate quickly and remotely with many people. Ideas involving computer mediated communication (CMC) and Computer Supported Collaborative Learning (CSCL)[93,94,95] have appeared in many fields from office to factory, and video games to education. Implementing a system which allows students to discuss the course material at leisure with other students and with teachers has made it possible to investigate the effectiveness of peer tuition and group working on a variety of scales. Collaborative learning has proven to be helpful in giving students a sense of achievement and competition with other students[60]. Technology can be used to bring together physically remote members of an educational environment. Yet, any remote system must take a lead from traditional teaching mechanisms to remain familiar[96,97]. Alternatively the communication network of the computer systems allows live communication to be facilitated. Remote lectures, laboratories and tutorials are possible[98].

However, the technical achievement of CSCW does not improve the learning outcomes. It may even detriment the social experience of meeting teachers and other students. Yet with the facility to have many students communicating together the diversity of education can be improved. Teachers' time can be used more efficiently; a potential for 1 teacher to address 1000's of students.

Collaborative working environments have grown in universities as students begin to use electronic mail and internet news facilities[99]. Systems such as that developed by Mühlhäuser[66] require a distributed architecture to provide information access, dissemination and collaboration. It is an important social aspect that people working away from educational establishments will become isolated without group oriented work. Having people work together is good for learning and facilitates brainstorming and group cooperation skills.

In the final stages of learning the student must be allowed to gauge their performance in order to consolidate. Thus the computer system might have to enable the teacher to set tasks which can be evaluated via the networked system. To ensure that some students are given the correct praise, the teacher will also require a level of privacy with different students. Generally however, all the phases of education are present because of the actual teacher involvement. A problem facing collaborative learning is passing control to different students in the system. Students must not be ignored and yet others must not take total control of a lesson. A teacher must have the ability to pass control around.

3.3 Conclusions

In theory good learning outcomes can be achieved if a system satisfies a good dialogue between teacher and student. The best dialogue originates in one-to-one individualised tuition. Two methods have been found in CBE which support this. Firstly, tuitional systems can provide temporally remote assistance, and CSCW can provide physically remote lecturers.

Even though teachers are physically remote they still cannot attend directly to large numbers of students easily, though the computer helps. Usually, the computer supports students logistically rather than educationally. With a tutoring system, the real lecturer can provide assistance through e-mail. Yet, for immediate feedback an artificial mechanism is required. One which automatically generates helpful responses.

Intelligent feedback can be generated automatically but cannot be hand-crafted in a simple manner that still remains relevant to the author. Some other form of authored courseware needs support the student educationally. The material must be directly related to the activities of the student and be selected using simple algorithms. This contrasts AI or implicit tuition where a teacher will not implicitly know when the material will be selected. The aim of assistance is to provide relevant feedback from which a student can build confidence. To achieve this the system should intrinsically satisfy the student's needs, select and replay pre-recorded advice in a mechanically intelligent way. An artificially generated advisory dialogue is often responsive to perceived needs but seldom to direct questioning.

Thus to understand what is required for a teacher to actively hand-craft courseware whilst promoting educational theories, two questions must be answered: 1) what changes in the patterns of teaching have assisted CBE? and 2) what properties have an effect upon the dialogues between the teachers and their students?

MacFarlane[54] proposed an initiative that aimed to improve student learning outcomes by actively involving teachers with the benefits of new technology. Laurillard[19] proposed a number of guidelines for improving the dialogue between the students and teachers via a computer medium.

MacFarlane's future patterns of teaching[54] identifies how improvements in the depth of student understanding result from **shifting** along the teaching/learning spectrum. These shifts are seen in all of the computer systems for education which have been examined so far. However none of them consist of all of these changes in the teaching patterns, nor should they. The shifts suggested are from:

i) Synchronous single location learning support to asynchronous networked learning support,

ii) Passive learning to active learning,

iii) Static presentation to dynamic presentation,

iv) Use of real objects to use of virtual objects,

v) Impassive delivery to supportive delivery,

vi) Omnimedia to multimedia,

vii) Unidirectional presentation to interactive presentation,

viii) Broadcast delivery to personal delivery.

Computer technology has given educationalists an exciting opportunity to make these shifts. The educational theory has suggested what is good to shift and the direction of potential improvements. But most of all, the teacher will require support in the new areas which differ from the older/static areas. This support can only be made apparent in the CBE authoring mechanism. Improved authoring will improve the effectiveness of courseware. The new methods are actually supporting the whole teaching process by making optimum use of technology in a traditional way that involves the communication between teacher and student.

To make these shifts conclusive, more educationally difficult areas must be satisfied as well. Technically the changes are possible with the advent of mechanisms such as the internet and multimedia. Yet, the necessary software for active learning and supportive delivery has not been so forthcoming. This might change if the end-users (teachers and students) drive the new developments further. This can only occur if practising teachers are given the opportunity to improve the outcomes of their students via a useful dialogue. Thus the teacher has control of the technology and not vice versa.

Laurillard[19] discusses in detail how the teacher/student environment must be supported. Retaining a dialogue between the student and teacher is important if the learning outcomes are to be improved. To do this requires any system to follow a series of rules for maintaining the role as teacher and thus satisfy learner interactions. Laurillard's guidelines suggested that the teacher-student dialogue should be discursive, adaptive, interactive and reflective. To ensure this dialogue exists she suggests guidelines that computer implementations should follow. They represent the kind of activities a teacher undertakes when communicating with a student.

i) Interpretation of student descriptions,

ii) Links to associate student descriptions to appropriate task selection,

iii) Use of models and algorithms for task generation,

iv) Intrinsic and extrinsic feedback,

v) Strategies to question students,

vi) Interpret descriptions and record/categorise the students' actions.

These details are hard to achieve well and knowing how they should be interpreted is difficult. The closest attempts appear in intelligent tutoring systems. The knowledge and training which a teacher has in order to carry out the activities above can only be artificially emulated by the ITS. An alternative is to aim to retain the educational dialogue through well authored courseware. Some of the teaching activities could be authored as components of simulations and programmed instruction but they cut back on the successfulness of student learning outcomes.

Students really need teachers to provide a system which will communicate with them in an advisory role. Thus the dialogue can be maintained as the student learns and is related to the work in hand. Yet the advice should lead towards more detailed learning concerns and follow effective teaching practices. Systems in the past have shown the way towards feasibly better teaching practices[62,100] but they have lacked the requirements for ensuring optimal student-tutor communication. In CBE this should be maintainable through motivated student activity and good HCI interfaces.

Demotivation can be avoided by a CBE system through good design but it is possible to motivate a student to learn directly. Keller's ARCS model[55] or Malone's[101] practical suggestions give some idea of ways in which this might be achieved. Malone's theory has indicated that **challenge**, **curiosity** and **fantasy** exist as motivational aspects which help to describe the attraction of computer games. Computer games often require active thought from the player to solve puzzles and learn new procedures but still remain motivating. In relation to motivation theory:

- challenge is concerned with the need to achieve desired goals, the uncertainty of the outcome (although without dire consequences), the purpose of the challenge (toy vs. tool †), the need to be affiliated, and finally to have self-esteem (actualization);

- curiosity concerns intrinsic motivation, wanting to discover, and to achieve satisfaction;

- fantasy concerns independent and dependent analogies, symbolic structures, metaphors and emotions[102].

3.3.1 Summary

This extended conclusion summarised the issues which relate to the hypotheses running though this thesis. It has discussed how implementations of computer-based learning have satisfied learning theories and the functions of teaching. The aim has been to see to what extent these computer programs have satisfied the three stages of education; prerequisite knowledge, practice of that new information and then consolidation to improve the student's performance.

It has been shown that visual preparation processes for prerequisite learning are considered well by CBE developers. However in the later stages of learning, students do not get the necessary teacher-defined support. This is because the authoring of a sufficient knowledge base and the necessary inference rules is hard, unusual and difficult. Other techniques such as CSCW are exploited but they are merely using the computer as a tool to connect humans. The original aim of the computer is to be a tool from which the student can learn or with which a teacher can teach. So, consideration of the media which a student will use and with which a teacher will create is required.

† Carroll[50] disagrees with Malone[101] about the users viewing a *tool* as something which should be easy to use since the outcome is already uncertain "(e.g. writing a good letter)", and a *toy* being difficult to use as part of the challenge. Carroll suggests that users only want to know "how does this system work?" Toys are challenging for a distinct purpose unlike tools.

Regardless of interaction and functionality, new computer strategies should ensure that material is organised to generate a useful student-computer dialogue. Authoring of this must always be considered carefully with any kind of CBE development. This is to improve the way in which material received by students represents the teachers' knowledge of a topic and not their understanding of the CBE system. Thus even though hypermedia, simulations and tutorial systems have a role to play in IT-based education, it is most likely that an advisory system will be authorable by a novice teacher and still improve educational outcomes. The system should uphold a good dialogue and the authoring should fulfill a familiar shift from traditional to future teaching patterns.

The material to be authored must cover all of the learning phases which are: prerequisite knowledge, practice of that knowledge, and consolidation of the knowledge. Thus there is a balance to be struck between the authoring and the learning of material within any educational system. This requires thought to be given to the ease of constructing good material and the subsequent guarantee for good learning outcomes.

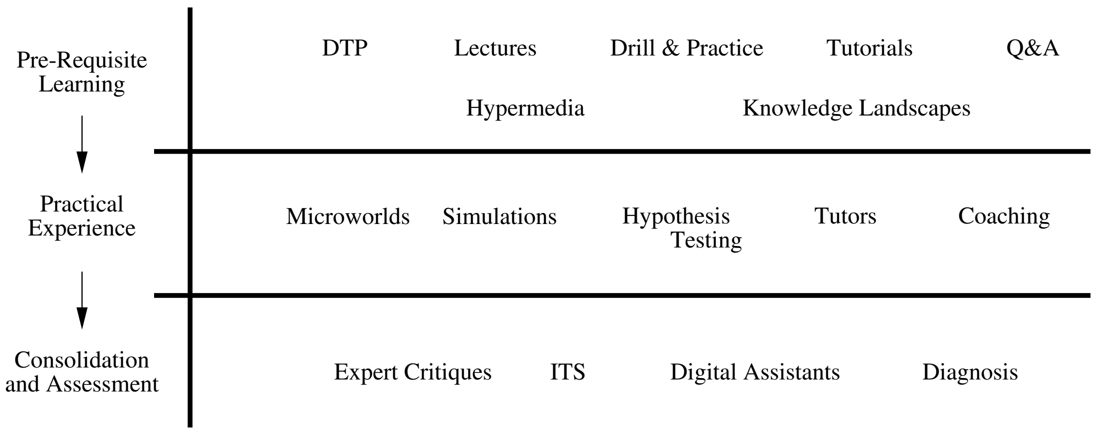


Figure 3.2: Balance of necessary authoring

The final depth of understanding results from collaborating and corroborating answers with experts. A supportive dialogue between teachers and students presented in an appropriate environment for learning should enable a student to fully understand the wider implications and critical assessments concerning a topic.

Chapter 4

Authoring Interactive Education

Teachers need to involve themselves with CBE for it to be a success, so they need to author it. Yet, the material they author needs to be both **interactive**, by making good use of the media, and **educational**, by facilitating a learning dialogue. The aim in this chapter is to describe a method of CBE design which will improve the production of systems that satisfy the users' (both teachers and students) tasks. Firstly a number of assumptions need to be made about the users as they author. Such a person is assumed to be alone, restricted in time and a novice. This situation occurs very often in real educational establishments since teachers want to be able to make their own contributions in education. For courses to remain contemporary, the teachers themselves must be able to modify and adapt courseware when required[103]. Although the authors are not considered to be computer enthusiasts, they are adept enough to make use of commonly available computer systems. In some cases, the authoring systems investigated date back to the mid-1960's and so computer literacy can range from understanding VDU usage to windows interaction.

The production of educational courses initially involves the identification of a target audience. A major aspect of the student's needs must be fulfilled by the educationalists (who also have needs) in the learning environment. This environment is made up of media and mechanisms which teachers use to assist them in tutoring students. According to Smith and Williams[104], educationalists who use IT are grouped into: enthusiastic amateurs, subject specialists and programmers, and integrated teams of higher educationalists (HE). They suggest that when evaluating courseware authoring tools for adoption, these different groups of educationalists use largely informal and non-methodological strategies. In this thesis it is assumed that the author will always be an IT amateur who will not necessarily be enthusiastic about computers and so may not know how to evaluate CBE tools. Although the teachers are attempting to use IT as the most suitable form of media to assist education, they should not need to make a complex evaluation when selecting CBE tools.

Rather than make an educationalist evaluate CBE mechanisms to determine their benefits, mechanisms should be sympathetic to the authors' needs, i.e. the final courseware should satisfy students' needs. The benefits of computer-based techniques should be obvious for them. Already, CBE mechanisms (e.g. hypermedia) have been shown to assist with learning requirements (chapter 3) but these will only be selected if an author can exploit them. The teacher must see that they can obtain good results by adopting a mechanism.

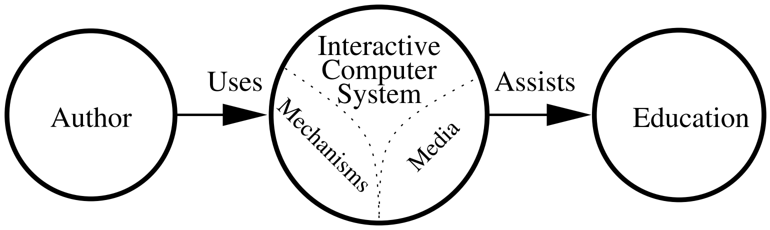


Figure 4.1: Interactive computer systems

Therefore, interactive computer systems for authoring educational material requires two aspects of design to be considered. Firstly, the media which are available for providing material upon must be evaluated. Secondly, the mechanisms and tools which a teacher uses in order to complete the task in hand will require selection. These two aspects provide the limitations or options for design. The options must be questioned and evaluated in relationship with each other to ensure that any design for an authoring system will satisfy the teachers' task-requirements. To conclude this chapter, a user-task based model will be presented in order to show how new designs for CBE systems might be developed or old ones might be criticized. It incorporates learning support facilities and the educational goal of providing a motivating medium as overriding criteria (a protocol). The model should then be able to highlight the problems that exist in attempting to make good use of computers in education. It should help CBE designers choose and design methods that make use of interactive computers effectively.

4.1 Facilitating Learning upon an Interactive Media

As already stated, there is a basic restriction which exists for the creation of teacher-generated course material. Teachers are bound to use the media that are available in order to satisfy their students' learning needs. The media are used to communicate the instructor's conceptions to the student. This occurs whether the teacher is or is not present. In the first case a medium is prepared before-hand to assist the teacher in making "descriptions of actions in the world."[19] In the latter case, the teacher must record and present the descriptions within the medium itself.

In general, the media used for live presentations do not necessarily have to support all of the course content. This is because the presentation is given to aid the actual learning goals that are proposed. It is not designed to be an all encompassing learning experience in itself, yet the optimum presentation of concepts is most important. A lecture is such an instance of a live educational environment using a monologue alongside the over-head projector (OHP) for the media. In contrast, the media which are used for viewing material at a later date without an instructor are very different. All relevant facts as well as concepts must be available and be presented well for repeated referral. However the mechanism for conveying the material is familiar to the viewer in both cases so that interaction with it can be intuitive. Books and videos are instances of pre-recorded media for educational environments. Examples of unfamiliar mechanisms for pre-recorded media are 8mm film which must be projected, or simulators such as SPICE[105] which must be learned before use.

In keeping within these limitations, authoring systems and their tools either apply extensions and imitations to educational technology or apply concepts from existing IT. Some examples of how educational technology has influenced the design of computer-based mechanisms for generating an environment for CBE are presented later. But firstly, that educational technology as a medium for education must be described.

4.1.1 Educational Technology Media Usage

Before considering the development of information technology for authoring educational material it is prudent to consider how all technology has influenced the mechanisms for creating courses on any educational technology. Educational technology (ET) provides a means of conveying information that the teacher wants to put across using a variety of illustrative media[59]. This is so for assisting in both live presentations of course material and in the recording of course material for distribution and personal use. The technology comes in the form of television, radio, tape, film, experiments, modelling, in addition to the more commonly used books, lecture notes and academic papers. The adoption of much educational technology has arisen because it allows the educational material to be reused with or without an instructor. Alternatively they are used to provide experiential learning which would be much harder and take much longer to describe verbally. Even with the advent of multimedia computer systems traditional ET's are still used to a large extent today[106].

The practicalities of any technique for education is of concern to the creators of course material. In order to convey the concepts, knowledge and understanding, teachers need to rely on their understanding of an ET in order to make good use of it. It is the perceived benefits of a particular ET such as an experiment that drive the author to use it. The difficulties of using computer systems may have contributed to the continued use of traditional ET even though IT has a high reusability value. For the same reason, students will only make use of technology to which they can relate. ET **applies** rather than **represents** the physical world in ways to which students can generally relate well.

The planning and production of a lesson which makes good use of educational technology can take many months. However ET can be used highly effectively if the financial resources are available. Some museums make use of this technology to provide the general public with tuitional material. Some universities make use of this technology to perform extremely fine demonstrations for special occasions - for example the BBC's Christmas lectures. Yet, some forms of ET are so hard to use that they are avoided in favour of, perhaps, less effective or efficient teaching methods. For example, producing a video can have many benefits when trying to teach microbiology. An experiment can be carried out in advance, the process and results videoed and then presented to the student. Without the technology, a greater amount of time and expense would be necessary to set up the experiment so that every student could carry it out and then experience the outcomes at varying levels of success. Even performing the experiment using a video camera attached to a microscope might not get the desired results since it too might not go to plan. A prerecorded video would give perfect results and be engineered to put across the concept more expressively, powerfully or even forcefully.

As a medium, ET cannot broaden the outcomes of the learning environment beyond that which the teacher has designed. Clever development of the material is required if a variety of ET media are to be used effectively for tuition. With computer-based media the system could possibly be designed to interact with and assist the teacher as well as the student. The information processing nature of the computer can also emulate the teacher to some extent and provide a broader range of learning outcomes within the learning environment than other forms of media and thus it should be exploited.

4.1.2 Computer Media Usage

Computer-based techniques for course delivery can provide lecturers with the opportunity to make use of a variety of effective methods of teaching on one medium. By replacing or simplifying previously complex authoring mechanisms of some media, information technology can advance the effectiveness of educational methods.

The goal of IT in education is to make it simpler for teachers to make the transition to more appropriate and effective ET. If, however, this is done incorrectly only dedication will make IT more effective for teaching. Traditional physical media for course material includes books, tapes, slides, films, videos, blackboards, experiments, laboratories, tutorial classes, libraries, references works, journals, classes and lectures. These are all available to the author for the production and presentation of educational material. In an age of information technology these traditional sources of course material can be digitised and improved to give students multimedia experiences. But this is only worth doing if it can definitely benefit the learning outcomes and makes more efficient use of the teacher's time.

The type of medium used for a course governs how it will be presented to an audience and how they will be able to use it. By providing a medium for experimentation, for example, the teacher will give the students tools which can be used to augment their intellect. These tools enable the student to hypothesise about problems at more complex levels than might be possible without them. IT media fall into 5 broad categories: display, browsing, experiment, tutoring and institutional[19]. Yet many of these media are used by external bodies to produce courses and not by the teachers themselves. These categories of media paraphrase Laurillard's[19] chapters on "analysing teaching media" because she covers the various areas of CBE well. However her examination looks at how the student is supported in the learning phases. This section views the authoring required for these media. These media are considered in their canonical form but hybrids do exist. Naturally, these hybrids cannot be said to take on all the advantages of the individual systems.

Additionally, the destination of courseware material is not just to the primary audience: i.e. the student. A course may be seen by other academics for possible inclusion in their own courses as resource documents. Furthermore when authoring the material the lecturers must be aware that they themselves will be reading the courseware in the future in order to assess its worth at that time. The courses will also be used as records of what has already been taught in order to avoid repetition. Taking a broader view, the computer-based production of courses must retain a lot of the academic quality which universities expect. Without understandable mechanisms for authoring, lecturers and teachers will not adopt computer technology in fear of it reducing their recognition as a good educationalist. The type of medium which will be used for authoring therefore must not only consider the students' learning needs but also the maintainability of the courseware.

Display Media

The blackboard and other visual media are used in conjunction with monologues and dialogues to satisfy many learning needs. The computer can emulate these audio-visual (AV) systems as well as make presentations more attractive, animated, and colourful. This can have motivational gains and engage the student's attention through analogies and fantasies. Furthermore, narratives can be recorded and played live to an audience providing perfect monologues. Thus the interactive computer system can quite easily provide a medium which displays information from many sources.

Systems such as NESTOR[65], HyperCOSTOC[72], PLATO[11], Authorware[67], and Powerpoint[107] amongst others can be used to create this type of media. The kinds of tools which they provide include text and graphics production, presentation ordering and the integration of other applications.

The abundance of systems for emulating the display media of education highlights the main advantage of CBE for teachers. They can now produce more visually stunning material. But the extra time cost is still high in relation to the learning outcomes. The learning outcomes from display media alone are not improved with better production tools. In particular the author of displayed media must carefully consider what is being displayed rather than how it is created[108]. This is one of the reasons for video and audio editing being difficult[109]. One example of this occurs when using colour in presentations because the author must be able to predict how the reader will react[110].

Generally the teacher is only good at predicting how the reader will react to the written word and the topic of education. Hence these are the areas which must be assisted during the production of display media. That is the organisation of text to provide coherent reasoning or the integration of specific tools necessary for a topic area.

Browsing Media

Some computer systems emulate the student's need to be able to search and find information about topics in order to increase their depth of understanding. Normally the library or book-shops will satisfy this need based upon the recommended texts indicated by teachers. On a computer-based system the student can make detailed searches for useful reference material[77].

To facilitate this educational browsing students are given access to hypertext and hypermedia systems. The teacher may now arrange information into conceptually-associated webs of information. Yet, hypertext is more effective for the learner if they construct their own knowledge. Thus, when the material is authored for the student it will lose its advantage over carefully constructed linear material. To be advantageous the material must be broad enough for the students to find information which they require to fill the gaps in their cognitive networks. Yet, the material must be guiding enough so that the student does not become lost and fail to learn what the teacher intended.

Intermedia[74] has already been described as one attempt to improve the integration of information across media on an Apple Macintosh platform. The Intermedia desktop uses WIMP-based interaction for content construction. Links can be authored between particular 'anchor' blocks (text or graphics) in any kind of document to similar anchor blocks in any other document. Using object-oriented programming, applications frameworks and building blocks are not techniques which can be easily learned within any multimedia system. Thus, the teacher requires support in the creation of this kind of learning media. In most hypermedia authoring systems the categories assigned to information are important. This relies on the media being able to identify fully, for later mechanical retrieval, its content. However this is all the learning that can be provided in its canonical form. It might be possible to improve how the authored material is used by posing questions of the reader and asking them to find certain information.

Experiments and their Simulators

In education the teacher may wish to use intrinsically responsive systems which provide the student with indicative representations of the real world. The implementation of these can come in three forms: mathematical simulations, microworlds, or logical models of the real world. Simulations can be developed and the mathematical properties of real world actions can be encoded. The logical models are hard to generate because they try to fix formal methods to informal reasoning. Such informal reasoning occurs in domains such as history, literature, music and foreign language learning.

The construction of a simulation requires the author to have a high degree of understanding of the properties of the situation or event which needs simulating. Most commonly a computer program can be written which has parameterised inputs, a mathematical function (which is the simulator function) and parameterised outputs. This function, which can consist of sub-functions, will be some form of representation of the world and should be expressed in a computable form. Because the simulation is aimed at describing an issue, it is never too complex and only needs to demonstrate the effect of particular stimulatory input parameters.

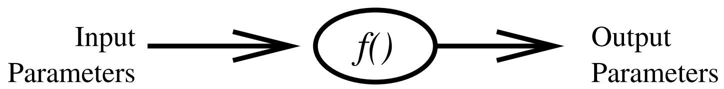


Figure 4.2: Simulated functions

In a basic simulator, the task must generate deterministic outputs from a known range of inputs. The teacher is required to identify the skills and the concepts which are to be learned. When encoding the functional model the input and output ranges must also have anticipate the kind of interaction possible and necessary.

This idea of simulations is developed further in what are known as microworlds. The author is required to develop a superset of these smaller simulations which embody essentially cause-and-effect relations. The microworld aims to provide access to more possibilities of interaction and description than a pure simulation could. Alternatively, the act of creating a model of real world situations can be rewarding to students in itself. In order to take advantage of this the teacher should wish to gear the modelling environment around the desired learning activities. This requires careful design because the student will need full freedom to express their own model and demonstrate it. Alternatively an available application, such as a spreadsheet, could be used to simulate a theoretic premise. The student can build their own spreadsheet 'models' and evaluate them.

Media for Tutoring

Traditionally the teacher has provided the backing and support for the non-interactive media (notes, slides, books) which they use and this support can be lost in CBE. A tutoring media must support or imitate the activities of a live tutor. This includes the backing and support which students need and this adds complexities for authors. The courses which provide tutorial interaction have taken the form of AI, generative programs and tutorial simulators. The medium, however, is a tool for the student to improve their learning. The ability for the students to interact with the computer media as easily as a non-interactive media is very important. Unfortunately, computer media for tutoring are seldom intuitive when supporting student interactivity.

For instance, it is possible to generate learning environments that imitate tutorials. There is little doubt that the majority of present-day tutoring systems have stemmed from systems of programmed instruction developed in the 1960s and the algorithms and strategies for generating the selection of subsequent tasks has become only slightly more extensive. They all provide extrinsic feedback to the learning process and the author must create and organise the exhibition of this feedback. The student interacts with this information passively and has little ability to decide the level of feedback or gain further information to clarify their learning.

To automate fully the tutoring process it is necessary for the teachers' knowledge of instruction, as well as their knowledge of particular topic-based concepts and facts, to be captured. It is hoped that artificial intelligence can provide this interactive support. An intelligent tutoring system can present information in ways that the student requires. It aims to provide support as recorded and as live material because the computer will act as its own presenter. Thus it can control the tuition or give the student control adaptively. Unfortunately good AI requires specialist authoring and in many cases can only assist a limited domain of knowledge.

The Institutional Medium

The final medium which is considered is the educational institute itself. This represents the medium which provides students with all the environmental requirements which they need in order to encourage good learning outcomes. In addition to scheduling times and curricula for courses, the institutions provide the students with a forum for discussing problems and ideas with other students and with expert teachers.

The IT mechanisms for supporting institutional needs are not authored but the logistical problems must be managed to reach pedagogical goals. The computer-based systems give the students and experts access to networks of terminals or workstations. These can be used asynchronously or synchronously for communicating.

However this mechanism still suffers from the same pedagogical problems as would a non-computer mediated institution if many teachers and experts were available. It relies on the teacher being able to use the computer to mediate this networked discussion properly.

4.1.3 Implications of Media Selection

The medium must be appropriate for the task of learning, but the teacher must be able to create with it intuitively. Students must not feel demotivated by the medium and it should pose no obstacles other than those posed by the exercises. Feedback is either the responsibility of a live lecturer or of the course material itself. Imitations of live presentations can use complex methods to generate feedback in respect of the teacher but imitations of recorded activities lack interactivity. Courses can be very comprehensive on recorded media but they still require a live teacher to satisfy all learning needs.

The main point is that imitating some traditional educational technology does not improve on the educational experience. Yet other benefits for the teacher may be gained, for example the reuse value. All of the different types of educational media (display, browse, simulation, tutoring, institution) have been emulated on a computer system. Unfortunately, the use of some professional media requires experienced users. It should not be important to train teachers to use IT but for IT to exploit the teacher's current abilities. But teachers need to learn new pedagogical techniques so that they can exploit them usefully in their teaching.

In order to maintain computerised tutoring's viability, authors must perceive that some educational benefit is evident when using a particular medium. These benefits make traditional methods of tuition simpler or cheaper, make previously costly media more viable, or they make previously unattainable learning styles a real possibility. For instance, if the authoring medium uses traditional techniques that are understood and verified as productive, assistance will not need to be given to the teacher. If a new, purely computerised medium is employed then the computer **must** provide some assistance or hints so that the user can relate the medium to those they already understand and want to use.

Some systems (virtual seminar[111]) try to emulate traditional media which were based on educational research, whereas some (LOGO) are specifically designed for CBE, and others are merely using the IT to satisfy some CBE requirement (networks to serve distributed learning). The choice and implementation of a medium for CBE will depend on the same criteria as traditional choices. Yet, the IT implementation should supersede the traditional medium or there would be no reason to use it later.

All media are generated from available technology. It constitutes the environment in which the student learns. In many computer-based learning systems the media are used merely in **conjunction** with other media including the teacher's voice. However to investigate the educational use of a computer, it must be considered in **relationship** with other media and with the teacher. The teacher's ability determines how well a medium will be used to facilitate learning.

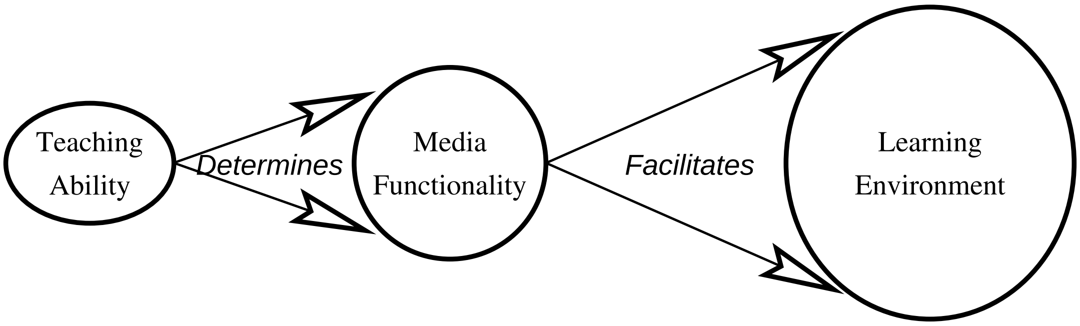


Figure 4.3: Components of an authoring system

Figure 4.3 shows that the teaching ability is expanded with the use of media and that it is the media which facilitate learning. With luck the media will also expand the learning environment to something beyond the sole ability of the original teacher by providing insights that even the teacher has not observed. By design, a computer medium should broaden traditional media's abilities by introducing extra educational feedback which can be intrinsically reflective. In other words, courseware: i) must exist in the learning environment, ii) must facilitate the medium that is used and the functionality of that medium, iii) must satisfy the activities of the teacher, i.e. the teaching tasks which they perform.

4.2 Computer-Based Authoring Mechanisms

Teachers use authoring systems to produce, on the unfamiliar computer medium, material from which students can learn. Since the medium is the only way in which communication between teacher and student can be established, its optimum use is most important. Teachers must present knowledge successfully to ensure a productive learning environment. Not only do they create products (courses, books, etc.) from which the students can learn, but the teachers themselves are valuable sources of knowledge and are interactively accessible to the student. This section looks at the options available for the kind of tools with which teachers can be provided for creating courseware on available computer-based media.

An author requires mechanisms which are intuitive to use for creating course material[112]. The extensive amounts of research into computer interfaces[11,15,16] should be able to ensure authoring mechanisms are effective and thus satisfy the students. IT arms courseware authors with a technology that facilitates the use of new media such as multimedia, hypermedia, ITS and other CBE systems as viable improvements over traditional educational media. The attractiveness of IT over a traditional form of instruction results from IT's ability to assist course production directly. Yet, if a teacher is expected to use an authoring tool it must meet their requirements as teachers and not require them to be knowledgeable in interface, AI, multimedia or hypermedia design. It is necessary for a protocol (or criteria for requirements) to exist to define a suitable boundary to the design of authoring mechanisms and tools. To assist authoring effectively, the computer software should be designed for teacher-computer interaction (TCI) so that authors can concentrate on the course rather than the technology. This suggests an overall improvement for CBE construction in that the student interface will be determined automatically and correctly, and not by the teacher.

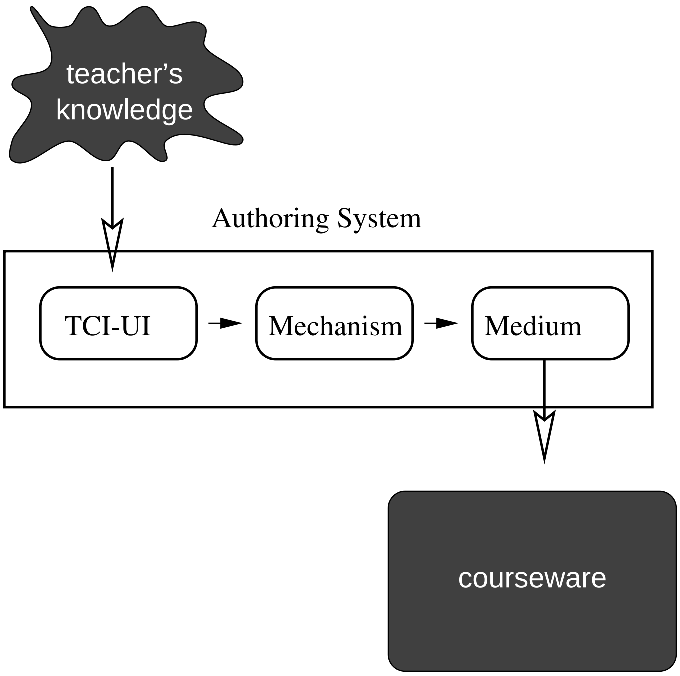


Figure 4.4: User interface for authoring

The TCI-UI (user interface) supports the teacher who uses a mechanism to create learning material that is accessible via an educational medium.

A particular medium is chosen so that students can be educated properly, yet the medium must also support the authoring technique suggested by the authoring system. To be entirely satisfactory the medium should present the courseware in a manner which is discursive, adaptive, interactive and reflective in general. Ideally the course material that a teacher authors is required to be stand alone, but in order to support the learning it is still necessary (and desirable) for teachers to interact with students.

In essence then, the tools for authoring can only be developed from some IT components. These components must be functionally effective for education and usable by teachers. It is already known that some IT tools on offer can do the former but are they supporting the teacher? That is, is the interface between the authoring system and the author satisfactory?

4.2.1 User Interfaces for Authoring

Teachers are required to capture on computer, via a user interface, their instructional, procedural and factual knowledge. In most cases only the latter is required, but some IT solutions for CBE require more. The student must be able to understand and use that material at some later time. The student will also have to be provided with a UI which makes good use of the authored material. Thus, designers of authoring systems must make use of research into HCI for the two kinds of users. There are a number of recognised issues which must be considered when designing any system which requires user interaction[16]. Firstly, *input* and *output* devices must be considered but in practice these are restricted to mouse, keyboard, screen and loudspeaker. In relation to this the variety of interface paradigms that can be utilised will be restricted though this might not always be the case, i.e. the mouse generally suggests menus and windows but not always. In relation to input, the *environment* in which a teacher will be working is important. The kind of time-scale to which they are working is going to be tight so the use of simple and familiar interactions is of paramount importance. The output is associated with the *tasks* which are being carried out in the case of a CBE system. It is the appropriateness of the educational medium selected for teaching which will govern the level of the learning outcomes.

Figure 4.5: User interface design components

Input and Environment

The teacher's task is to make use of the computer effectively for creating courseware. Teachers are users with particular abilities and knowledge and they will require a variety of tools to assist in carrying out their tasks. The outcome of their efforts is extremely important to the educational institutions and to themselves so it must be effective. Teachers often have little time to learn new skills, hence they will need *support* as they use an authoring tool, either from the computer or from a third party. The level of support depends upon the degree of intersection that appears between the teacher's abilities and the tools provided. Furthermore, unlike a general interface which has to be flexible and give way to many interactive situations, the teacher's interface only has to relate to a teacher's way of working.

Preece[113] identifies the UI styles as command languages, menus, natural language, question & answer dialogues, form filling and direction manipulation. The most flexible is the command language or programming language. Since they are designed for general purpose applications they do not offer a suitable mechanism for making interfaces that are easy to use. The obscurity of programming languages and the variance in paradigms can make the movement from one system to another very difficult. Primitive menu-based systems should not be confused with pull-down menus found within a WIMP environment. The former gives the user a series of options of which one must be chosen to proceed. A hierarchy of menus can be used to give a user access to a variety of functions easily but this is only useful if the depth and breadth of items is limited. Beyond this the user can find it difficult to find a menu option again if they seldom use the system. Intelligently interpreted natural language offers the most intuitive method for interaction at a simple level when only minor changes within the authoring are required. Yet for detailed construction, describing every particular aspect, eventuality and possible situation would be tiresome. Although very popular, it might not be best to implement an interface using direct manipulation, i.e. a WIMP (Windows, Icons, Menus, Pointers) environment[114]. Because of the prevalence of direct manipulation, its avoidance might not be possible. In this case, the functionality it provides should not be relied upon. Problems are known to occur as users look for buttons and menu items which are effectively hidden[112].

Most definitely, teachers should not have to become involved in learning new programming methods to enable course creation. Specifically some authoring system designs which are available on computers for CBE do not draw upon traditional construction design. Several alternatives to text-based programming languages have been proposed. Programming by demonstration is one such concept by Myers[115]. This can enable simulations to be generated without traditional programming skills.

User ability restrictions

Even though there are many interface styles and i/o metaphors, a restriction must be placed upon the choices in favour of the learning outcomes. In general, teachers are not competent to design the user-interfaces which students use — that a "point-and-click", multimedia, multi-window presentation is inherently and automatically good is a naive view of what determines a high quality user-interface. Either special development teams must be employed, or the authoring system used must minimise the variety of possible interfaces and adopt a proven strategy. The system designer must minimise the variety of mechanisms and tools to those which a user knows or can easily learn.

When educationalists have to select a mechanism with which to author, they will give themselves a number of criteria from which they must choose one. Two of these should be the mechanism's capability for creating a motivating environment and its capability of supporting the learning phases. These rules to which the input must adhere will be prominent in the tools that are used to create the information for learning if that learning is going to be authored successfully. The rules might be realised through the design of the student's interface and the style of communication in the interface. This context for learning is often designed superficially in favour of the learning content. For instance, a simulation might theoretically be excellent but if the learner's interface does not follow the rules for a good mechanism it might be practically useless.

Thus to summarise, the rules give the authoring system designers a criterion to judge the usability of their system. It ensures that the level of interaction will be appropriate for the teachers whilst retaining a good learning environment. Thus it guides possible choices of CBE media (see section 4.1) that can be used by teachers for education.

Output and tasks

Tools are provided to assist a teacher in the production of educational information. A gross simplification of the required knowledge for teaching expresses it in two forms[116]. Firstly, there is the topic knowledge which the teacher wishes to describe; secondly, there is the teaching-strategy knowledge which the teacher uses to react to students' descriptions. The tools which are provided for creating this information have some similarity to the tools used by UI designers. Essentially, the teacher is generating a UI for students which allows them to interact (engage in a dialogue) with the computer-based topic material. Notice that general purpose tools or integrated toolkits can be used to produce both kinds of information (topic and tuitional). Communication style with these tools is all important and so is the material which is generated with them.

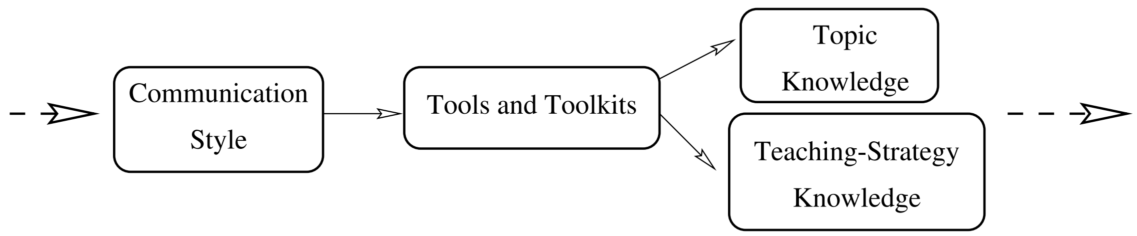


Figure 4.6: User interface tools

In order to design an effective authoring system, the kinds of information which will be produced on media should be understood. This will enable the UI to be designed around the authoring tasks. By understanding the aims for computer-based media which teachers have, the interactive components can be identified and catered for. This is in contrast to examining the tools available with computer systems and utilising them in the construction of learning materials. It is also in contrast but related to adapting IT to the construction of material for satisfying learning needs.

In some ways these two forms of necessary information relate to the model suggested by Tait[117] for creating Toolbook documents. His design was based on the facilities which Toolbook offers thus it moves away from the more traditional AI approach. This model is composed of three authored parts. These are the *content*, the *presentation* and the *interaction*. Content and presentation constitute the topic knowledge, the presentation and interaction constitute the teaching strategy. The presentation appears twice because it can be part of the content and remain static and specific to the topic information; yet the presentation might also be adaptive in other ways to the rules of teaching in order to manipulate the topic's interpretation. Thus these two different kinds of presentation are identified here as: layout presentation and delivery presentation. Thus:

- The content is the information which the lecturer wants to divulge. Tait[117] states that content does not imply a knowledge base since the material cannot be understood and related to other knowledge by mechanical processes. No rules are used to define the semantics of the content but they may define the constructs. In addition, the content can satisfy the learning needs alone if it is written well and the student has the skill to interpret it efficiently.

- Presentation is the method by which the lecturer will put across that content either in its layout or its delivery. The layout represents the typeface used (and the juxtaposition material) but can also represent the timing and concurrency of integrated media. A video might accompany a narrative or precede an explanatory text, for example. The delivery may affect how the content is interpreted. The content can be obscured or enhanced by the delivery. A good delivery will simplify transfer of content into the student's memory and provide associations and options for recapitulations that are necessary for learning.

- How the students interact with the generated courseware can vary from passive reading to conversing with a fully-fledged intelligent tutor. Laurillard's designs for the production of teaching material focuses on what is termed here as interaction. This represents the material which is authored to provide a student with a learning environment that also adapts and reflects upon the student's descriptions of the world. Laurillard's interactivity algorithms can be seen to modify the content or presentation to suit these descriptions and thus provide corrective or supportive information. Thus Laurillard's interaction is only a small part of the kind of interaction which a teacher is often asked to author in some CAL systems. That is, the author may additionally have to author windows, menus, buttons and so on even though this ought not be their primary task.

Note that content, presentation and interaction are necessary to satisfy Laurillard's requirements that material should be discursive, adaptive, interactive and reflective in their support of students learning requirements (pp205). Each of these requirements are satisfied in some way by all of the three types of information. For example, reflection can be content, presentation or interaction based when it is authored. Thus it might simply be some reflective comment, or it might require the student to engage in activities to enforce reiteration of the new concepts.

Furthermore, a beneficial learning dialogue requires the students' interactions to be under their own control to some extent. Merrill[58] suggests that there are 4 levels of control which can be exercised when learning with a computer.

Content selection - what to do next.

Display selection - what type of presentation next.

Conscious cognition - way in which a student chooses to process information.

Meta-cognition - way in which a student's interaction is afforded or guided.

Yet total control would leave the student with little support or assistance during learning. Courseware must take these levels of control into account.

4.2.2 Computer Tools and Mechanisms

Rather than discuss the particular tools and mechanisms that are in existence, the functions which the tools and mechanisms provide are identified. There are two functions required for generating topic content and tutorial strategies.

1. Content Development Functions

Firstly, there is the development of topic content which the student passively browses but may actively think about.

- *Text and Graphics*

Text is the primary form of medium that is required by the developers of courseware. Text editors provide functions to enable the entry of the written word but documents also need formatting information. This suggests how the text might appear or what the text might represent. Formatting styles exist in applications such as t–roff (on Unix operating systems), and more recently LaTeX[118]. Wordprocessors use mechanisms such as RTF to provide a formatting scheme. Some recent schemes have realised that there is additional information in the way in which the text is to be represented. An 'emphasised' word is more important than the fact that it is simply presented in a bold typeface. Then, italics, bold or underlining could be used whenever emphasis is required. One method for authoring material without the need for inline formatting is simply to use a formatting grammar. This grammar is used to interpret marks in the document text to give the strings of characters meaning. Thus a paragraph can be defined in a document with "paragraph markers". The SGML grammar[12] enables text to be distinguished in terms of headers, lists and paragraphed text. All these are useful for the author when producing distributable material. To improve production, guidelines and templates have be adopted to make some complicated but flexible systems easier to use. Others provide a form-filling style of interaction for content construction, e.g. PowerPoint wizards.

It is possible for tools to be made available for producing good graphical presentations. Teachers know how to produce pictures on paper and have some experience of how to use them in education. The functions which they may require are free-hand sketching, image manipulation and processing, and technical drawing capabilities. Yet they also need methods of transferring the pictures and diagrams into the textual context. It could be a better idea is to paste graphics into a course from another dedicated application (such as a virtual sketchpad). This translates into importing a resource from a general-purpose tool or a library of graphical images.

- *Resources*

In addition to their own work, an author may wish to make use of the work of others. This may take the form of images, diagrams, text, sounds, applications authored by other teachers, simulators or hypertext webs. Because resources can be integrated into courseware, teachers need tools to manage the resources and help them form connections between resources. Intermedia[74] does this using a direct manipulation style of interaction but HTML (Hyper-Text Markup Language[119]) on the other hand uses textual anchors with URL's (Universal Resource Locators). Problems are apparent if any resource is held at a remote location. A change in its status at that location may affect how the author intended to use that resource. A film may no longer exist or say exactly what the lecturer selected it for. Copying the resource locally can cause copyright problems as well as problems associated with storage requirements. More than just copy other material as it stands, authors may wish to annotate the individual media with other media. For example, a diagram may need the addition of textual labels or a film may require an extra narrative. The functions for merging resources might also be required.

Authoring material as links of resources, as opposed to resources with linear media is difficult. The author must understand how the web of information can be traversed and anticipate the students' "voyages". In some respects the authoring of these links could be construed as authoring the presentation of content. This is due to the referencing of material encouraging the way in which the content is interpreted. It is important therefore to understand and utilise the implications of making a conceptual link to material. This is seldom assisted or considered and depends entirely on the author's discretion.

- *Organisers*

When authoring course material, assistance during the development process will be needed. The extent of assistance will depend upon the author's experience. Tools for organising information for communication include mind-maps[10], concept maps[120] and so on. Many of these techniques have been implemented in the hope of assisting courseware development but the interfaces can be complex. IDE[121] tries to employ links of rationales (figure 4.7) which enable the author to make decisions about the robustness of the content. This will ensure that there are few flaws in the topic presented to the student.

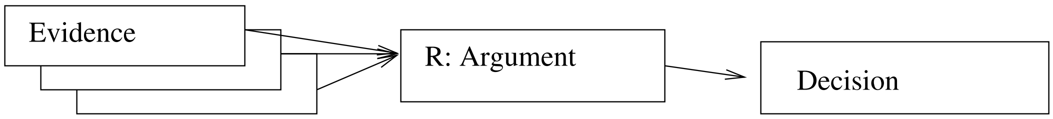


Figure 4.7: IDE model

The author would present evidence which leads to reasoning about the decision to create a topic within a lecture[122]. Other aids to software engineering might have some useful functionality for courseware authoring. CASE tools enable a software designer to specify and prove properties about a piece of software. Because of their quasi-formal notation, similar properties about the content for a topic might be provable. The content can be generated according to topic guidelines thus providing the author with a well-defined content structure.

Organising the way in which information is put across is distinctly different from the authoring of material itself. It involves deciding timings, use of media, attracting the audience and so on. A variety of studies have been made to understand how this kind of information can be usefully captured digitally. The art of film craft and news and television production is one such area[123,124].

2. Teaching Strategy Development Functions

Secondly, there is the development of teaching strategies which assist the student to engage actively in the phases of learning.

The creation of teaching strategy knowledge has been introduced to the teacher's workload. In the past, the teacher will most often have engaged in a teaching strategy 'live' and thus authored their interaction with students on-the-fly. By using educational technology, be it computer or non-computer based, the teaching strategy has to be prepared. The computer's method of teaching the student needs to be defined. From this information, most of the learning needs will be satisfied via the automated system. However this definition is the hardest aspect of courseware development to be produced. Laurillard's[19] phenomenographic outlook for designing teaching strategies describes some of the teaching and learning requirements which her model defines. A teacher usually authors the discursive material but the adaptive, interactive and reflective material is a lot harder to encode.

Two further pieces of knowledge must be authored to achieve the adaptive, interactive and reflective aspects of teaching. First the teaching strategy must be defined in such terms that the computer system can interpret and act upon them. Secondly, the student's interaction with the tutoring system must be recorded and interpreted so that the computer can respond to the individual accurately. Creating these two pieces of knowledge requires tools and mechanisms. Since the authoring system is creating a user interface for students, it can be said that user interface design can guide the design of authoring systems. For creating responsive interaction 3 types of mechanism exist. These record:

- algorithms for generating feedback to user descriptions,
- logic inference rules for judging the user as an individual, and finally
- anticipated user actions and provide an appropriate interactive metaphor.

These three mechanisms are not entirely isolated and they do intersect in real authoring systems.

• *Algorithm Production*

A teaching strategy can be defined on a computer as a series of algorithms that respond to the activities of the student. These algorithms decide upon what information in the corpus to display next, or how to react accurately to the student's requests. The algorithms may be used to manipulate and reuse the content in predefined ways. The way in which information is utilised will depend upon the student's prior and current responses and the algorithms can take this into account. Thus a model of the student will exist in the variables of the algorithm. Generally these variables are limited to recording which information students have already viewed, how long they looked at it and if they have answered the set exercises (if any).

Usually algorithms have to be programmed by the lecturer in a computer programming language. There are a variety of programming styles which are available from research into simplifying programming[125,126,127]. Because of the difficulties involved in learning these languages, CBE developers have attempted to give lecturers tools and an environment with which they can program more easily. In recent years, these languages have been incorporated within user-interface design environments that emphasise using buttons, menus, windows and so on. These authoring tools never seem to incorporate good principles for teaching nor serve to enrich the learning environment. More likely they serve to impede the learning environment. Some systems have tried to overcome this issue by incorporating templates and pre-programmed scripts[65,72,117] although these again take some time to learn before they can be exploited.

• *Logic toolkits*

It is possible to simplify the authoring of teaching strategies for courseware by reducing the authoring operations to purely logical functions. Courseware is authored as before but parameters are added to identify the category of the information sections. The system can interpret any part of the course and use the authored logical functions to decide how the use them. The author may use Boolean operations, set algebra or other mathematical operations to program the selection of information. As well as utilising the categories defined for the information an in-built model of the student can also be used. Thus as the student works with the system, their interactions will modify the model. The teacher can author operations which will interrogate the model when making decisions about which information to display to that student next. Of course, a teacher could in theory program a computer to do this but the abstraction of the programming to a toolkit of logic operations makes the process closer to an organisational problem.

These toolkits still rely on the teachers understanding something about the mathematical operations they are given to use. They must also be able to categorise their tuitional material either as the system requires or in their own way. In both cases they must then know how to use the categories and operations in ways that will eventually teach the student users. The teacher must predict the students' activities to define a useful combination of logical functions.

- *Anticipated Actions*

An alternative method to coding algorithms or defining the logical structure is to respond directly to actions. The action-event sequence is bi-directional but generally uses the least amount of prior knowledge about the student. The author cannot define an accurate student model but they can adopt the UIMS mechanism to define actions and events. Most commonly the teacher defines the interaction that a student has with the system and provides the responses as necessary. For example, when the teacher wants the student to interact with an audio and graphical simulator which they have developed they will need to define the interaction in terms of the actions and the effects this will cause. This can be done best using a UIMS toolkit.

An author may not have the experience to understand how to get the most from these UI concepts and will use them incorrectly. The benefits to simplifying the programming of interactive functions that are provided by frames, windows, callbacks, messaging, dialogue boxes and so on could be lost on a novice author. This will induce demotivated use of the system by the student also. Laurillard's model is also to ensure that motivation is considered and that there is some relationship between motivation and feedback. With some of the environments which could be authored, a student may have to wrestle with the interface (UIMS developed by a teacher). Anything which could cause the student user to be demotivated should be avoided. If it cannot be avoided it should be anticipated and the difficulties reduced.

Integrating various media from other applications within courseware can require a variety of complex programming skills not always known to teachers. Integrating different applications will result in a variety of interface styles being utilised. The various applications must retain a familiar aspect so that the users can work with the educational information. Extensively developed UI applications such as Microsoft Office or X windows are only just satisfying this requirement.

4.2.3 Implications of Mechanisms

Firstly, several user interface design factors have been highlighted. These are the environment, abilities and tasks of teaching. The environment of a computer-based system must account for a teacher's normal resources and time available. The teacher's abilities and motivations must be considered to ensure that interaction is restricted to the capabilities and aspirations of the teacher. Lastly, the tasks must relate to the teacher's actual requirements, that of organising information for students. This information is both the content and the teaching strategies.

To implement these interface requirements, the tools must be selected from those which are available. For education these two kinds of information can be authored separately. Content uses text, resources, organisers and layout. For teaching strategies, the system is required to consider the authoring via programs, toolkits and the anticipation of actions.

4.3 CBE Design Protocol

Authoring systems and the evolving novel teaching practices are the products of computer-based learning research. It is the software for the production of educational courses. The aim of the authoring system is to facilitate the production of courseware which will support good learning and teaching strategies as outlined in chapter 2. Yet it is important for authoring to adopt teaching practices that support the learning environment and to provide an instructive dialogue between the student and the CBE courseware. The final courseware requires well produced material and support for accessing that material. Thus the authors' tuitional goals and the readers' learning needs must be considered[34,36] whilst the courseware is being produced.

Mechanisms for courseware authoring have unknowingly assumed teachers are UI designers and programmers. Alternatively, when mechanisms are designed to be simple, the resulting courseware makes less educational use of the the IT media. Furthermore, by channelling the teachers' understanding into a relatively underused IT media, learning outcomes are less than with a more intuitive media of which a teacher can make good use. Thus, the end users of education must be able to make good use of the media and mechanisms with which they are provided. Otherwise, all participant's education will suffer. For a system to be designed with these end users in mind a number of rules must be followed. They constitute a **protocol** for authoring system design. The protocol must satisfy the primary design requirements for authoring systems and the learning environment for which they provide.

To design software for authoring, two questions must be answered to satisfy the software's requirements. The two questions arise out of the authoring systems investigated through this chapter. That is, the mechanisms and the media of teaching. The two questions are: 1) how to identify and develop mechanisms which support the teachers' needs as they construct motivating course material? IT similarly has prepared material which can satisfy some of the learning requirements and has tools to empower teacher-based production. But IT is extremely versatile and it is too easy to create tools which are familiar to the designer of the tools but not those using the tool. 2) how to select and make good use of the IT medium for facilitating learning? The student requires a system which will present authored material in intuitive ways. For example, they should not be looking for the ON button but opening books. They should not try to find the menu to change font, but want to read the text regardless of how it is displayed[19].

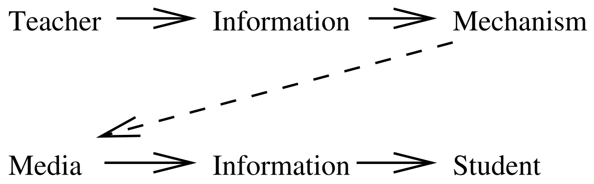


Figure 4.8: Use of mechanisms

The teacher encodes information through the use of the authoring mechanism. The media re-presents the information by decoding it for the student[59,128].

The system must satisfy the student's learning environment. The students' phases of learning are to have goals, actions and feedback satisfied by the tuitional strategies. Whereas the teaching strategies must originate, maintain and fulfill the motivation of the students in the learning situation. So, the final courseware environment should clearly satisfy these aims and outcomes. Yet overall, the teacher's abilities must be observed when determining which computer-based mechanism for learning is utilised. Ultimately, in terms of teacher-student dialogue and educational value but not teacher ability, the three aspects during the development of any system are:-

1. Can the learning goals be made plain and clear? Is the courseware discursive with the student?

2. Can the learning needs and desires be maintained? Can the courseware adapt and interact with the students?

3. Can the outcomes be fulfilled and consolidated? Does the student have the opportunity to reflect upon the courseware.

Based upon the IT tasks, the design of an authoring system must take into account the UI, available tools and the type of information to be authored. A designer must select these in the right order so that later choices are made from the correct standpoint. The protocol defines this as:

1) Choose a familiar educational environment. The student and teacher will be able to relate to this environment well. The interaction will be more transparent when designed well. The environment defines the media to which the teachers and students have access.

2) Select an interaction metaphor which will complement the environment. The ways in which students and teachers communicate with the CBE environment must be intuitive. The environment should not place extra burdens upon the teacher in particular. The teachers are the users that will be creating information from their knowledge in that environment.

3) Develop or adopt tools which teachers understand or can learn quickly. To generate courseware teachers need tools. Having decided upon a method by which the teachers can interact they must have the means to make tutorial information. This will exist upon the media that is represented in the environment.

4) Organise and present the information in ways which the environment allows, which the student will understand and relate to, and which will not be hidden from the teacher. The teacher will be able to predict the student interactions as they generate the course material. The anticipation of student interactions will partially ensure that the material delivered is appropriate to the students' needs.

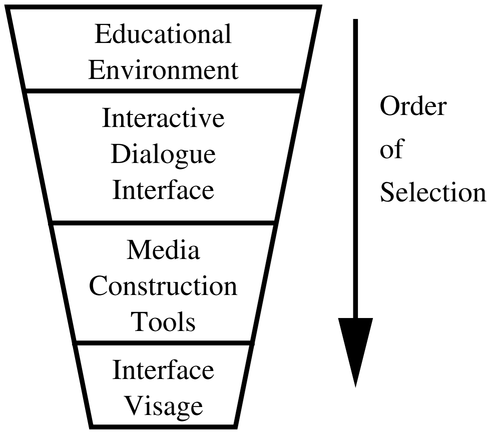


Figure 4.9: System design sequence

The protocol is not a panacea. It encompasses the design phases of the style of authoring system required by this thesis. That is, hand-crafted for generating a deep learning environment. It may, nevertheless, help to initiate development of a strategy for more general education systems.

4.4 Conclusions

It was hypothesised at the start of this chapter that the media and the mechanism for CBE were not properly accounted for in the design of authoring systems. Teachers are unable to generate information successfully with authoring systems because the IT *media* assumes a high level of IT ability. By giving teachers flexible systems for creating course material they often are able to build their own student interfaces. This means that the student's interaction relies on the author's ability to design UIs. Hence it is also important for system designers to ensure that good interactive metaphors are used. This can be done by automating this part of the authoring process or by standardising the UI for the student. Furthermore the IT *mechanisms* do not relate well to the tasks and activities of the teachers. Most teachers are not media designers and cannot successfully take advantage of the opportunities made viable by computer systems for presentation and interaction. They are not graphic artists, presentation designers, publishers and so on. Yet, a teacher **is** an academic and thus is able to produce the content of information and is able to organise it into digestible components. Therefore authoring systems should augment a teacher's best attributes. Those of content creator (author) and disseminator (organiser).

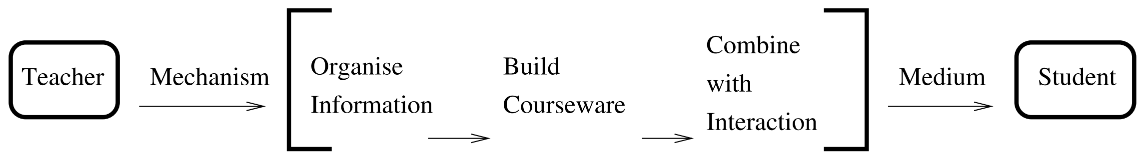


Figure 4.10: The first result of the Design Protocol

The protocol for designing authoring systems hypothesises that an appropriate academic environment is defined before applying an IT model to it. This means that the media and mechanisms will be familiar to the users. The intuitive metaphor should ensure that a high level of practical quality is retained in the teachers' interaction with the CBE authoring system (Figure 4.10). Although this primary restriction of the protocol will initially reduce the variety of approaches to CBE in the future more IT based techniques will become familiar than they are currently. Therefore, the restriction will seem to apply less compared to the traditional ET methods. It is now required for this model to be explored further with experimental systems.

Chapter 5

Preparing For Interactive Education

This chapter discusses the prospect of converting a traditional method of course delivery onto a computer based system. The on-line lecture (OLL) concept[1] centres on the use of the Book Emulator[5,129] as a tool for preparing and presenting lectures. The presentation is based on the conventional lecture supported by the overhead (OHP) or 35mm slide projector. The Book Emulator was used rather than writing an entirely new system or using a system such as ToolBook or Authorware because the Book Emulator handles all of the general user-interaction whilst allowing the flexibility to interface with external programs that manipulate data exactly as necessary. The book also affords a slide metaphor well since each two page spread can represent the landscape view of a slide.

The on-line slides were to be no less useful than physical lecture slides and so were to be used in a lecturing environment or viewed privately by the student. The aim was to examine the computerised lecturing mechanisms required to facilitate an educational dialogue, and how they could be incorporated and utilized without any more difficulty than conventional OHP style lecturing. In order to achieve this goal, some standard lecturing techniques are examined along with their usefulness for student learning. With this information the implementation of the facilities for constructing, presenting and receiving lectures via the Book Emulator were constructed.

5.1 Lecture Aims and Requirements

Lectures are a useful vehicle for examining the authoring requirements of tertiary level academics. In universities, mass instruction methods are the most common for information delivery[59]. Lectures can be constructed and modified quickly by lecturers and they can deliver the same information efficiently to many students. The lecturer's aim is to transfer information to students' short-term memories accurately and to long-term memories rapidly. Lectures should primarily present new information to students, orientate them towards learning new concepts and principles, and then motivate further study[100,130]. Most of all though, the lecturer provides a human face to education and a focus for learning[1]. They facilitate an arena for presenting new topics to novices in the field and developing their domain knowledge. To this extent, the listener need not have much prerequisite knowledge although a prepared student will probably gain the most from lectures.

The spoken word supplemented with a blackboard is an old form of lecture delivery and is generally still used today. The blackboard has given way to the slide projector in recent years *(20 years or so).* Slides can be prepared in advance with experimental data which might be laborious to copy onto a blackboard and error prone in copying back on to paper. The alternative is to provide every member of the audience with a copy which could be expensive, unfeasible and may break rules of copyright. Furthermore, using a blackboard rather than providing handouts keeps the students' attention upon the speaker rather than on the notes.

It may seem simple to facilitate lectures with modern computer systems because the graphic design of posters, letters and magazines has been well established. Yet, is the use of a computer for lectures merely its employment as a desk-top publishing (DTP) or word-processing (WP) systems? It might be assumed that a tool which can create newspapers, books, leaflets and so on will have a use as a tool for creating lectures. However, the production of a book, for instance, requires a lot more information to be held about the look of the document than would a lecture. More facilities are available to the lecturer using a DTP package than are required for quickly making lecture slides. Presuming to adopt an established yet differently specialised presentation method is not a solution.

The time taken to create a lecture is normally the time taken to write neatly what is to be said. However with many forms of educational technology, the time taken to learn the media and discover how to make use of it effectively will also come into play. The difficulty of using any kind of technology to automate lectures is likely to be the reason for their neglect; specifically when using computers and

IT. A lecturer will not persevere with a difficult technology for long - even when the extra time taken to create with it will ultimately be recouped later. Obviously a pre-recorded lecture can be given many times, each time perfectly. It is suggested that removing pauses for thought, *mazes[8]* † and the need for a student to copy down notes, could reduce a one-hour live lecture to 20 minutes of recorded lecture. Rather than fill this time with a more complex and lengthy lecture, the extra 40 minutes could be used for experiential learning.

On-line lectures have two types of user and one practical requirement: authors and readers, and a mechanism for communication. The authors (lecturers) play the **active** part in a presentation since they are giving the information. The readers (members of the audience) play the **passive** part in a presentation since they *merely* receive information[96]. Pure lectures are taken to be uni-directional.

Authors — According to Newble and Cannon[130], a good lecturer:

- presents material clearly and logically,
- enables the student to understand the basic principles of the subject,
- can be heard clearly,
- makes the material intelligibly meaningful,
- adequately covers the ground,
- maintains continuity in the course,
- is constructive and helpful when criticizing,
- shows an expert knowledge of the subject,
- adopts an appropriate pace,
- includes material not readily accessible in textbooks,
- is concise,
- illustrates the practical applications of the theory of the subject.

(p 4; after Cooper and Foy, 1967.)

It can be seen that almost all of these attributes are solely dependent upon the abilities of the lecturers and not the computer. To assist the practice of the attributes, the lecturer will make use of a variety of lecturable media, yet care must

† A maze is the term used for pre-maturely ending sentences in speech.

be taken. For example, some textual, audio and visual reference material may appear stimulating and exciting but be entirely inappropriate. Yet in contrast, the results of experiments, for example, will provide documentary evidence and thus be a good use of reference material. The object is to not distract the student with information that is too complex, too stark or not of primary relevance. Some media allow the lecturer to use both sight and sound, in an attempt to enforce more associations in a learner's memory[16,20]. Tape-slide combinations and videos allow a lecturer to prepare material for a student to see and hear. Blackboards and overhead projectors are useful for diagrammatically emphasising the lecturer's spoken word 'on-the-fly'.

In any live lecture presentation an orator can emphasize points or make qualifying statements in addition to physically provided resources. It reduces the cognitive load on the student too since much of the information in a lecture needs only to be pointed out aurally. Of course, other physical resources such as the senses of smell, taste and touch, may be employed in order to pass on information. Sometimes other props. (e.g. a skeleton or an experiment) may also be used to give more detail in the presentation. In essence, the lecturer can only select suitable techniques and resources that exist in the bounds of the educational environment.

Readers — The delivery of information to a mass contingent of students will require orientation by starting from the foundations of their knowledge. Therefore the presentation should be paced well, spoken clearly and allow the audience to understand what is being delivered at that time. Because lecture time is restricted and information must be rapidly and accurately presented, it is important to adhere to instructional design principles. Newble and Cannon[130] suggest that the prepared material: is *relevant*, has *links* to prerequisite knowledge, is *simple* in language, *emphasizes* points to compensate for the lack of detail, and is always *consistent* in the use of pattern and style. Disregarding these issues will reduce the learners' attentiveness during the lecture presentation and allow them to form negative feelings towards future lectures.

In addition to the lecture itself, lecture notes for orientating the audience should also be provided. These are often written with private study, rather than in-lecture use, in mind. The students will be able to pace themselves by reading the lecture notes before and after the lecture in addition to making their own annotations on the material. Of course the notes cannot include many of the techniques that might be used during the live lecture but they can incorporate reminders.

While students like to have a sense of control in the learning that they do, they are also pleased to be guided through difficulties. It is after the lecture, during private study, that most of the self-taught learning occurs with sources of information such as books, tutorials, conversations with peers and the support of notes the collected during lecture. Motivation for this study comes from the student trying to understand and complete course work or to make discoveries for personal interests. The lecture material provides scope and structure to private study and the lecture theatre is a place where the student can interact intelligently with the lecturer and other students.

In summary, the student requires the opportunity to approach lectures with motivation and leave with a sense of purpose or satisfaction. They must have the material which will orientate their continued efforts to establish their knowledge.

5.1.1 Lecturing Tools

It is the use of technology and techniques that assists lecturers in exploiting their attributes as good lecturers. Although lecturers will have their own views about how to lecture there are many techniques available for ensuring high quality outcomes[130] (pp 10,14).

Logistically, problems are evident in the use of some lecture media, most commonly when using a blackboard or whiteboard. For instance, the lecturer must consider the colour of chalk or pens being used. Yellow and white chalk rather than red, dark blue or green. On a white board, dark blue, green and black are excellent but red and yellow are not. For a computer-based lecture the problems and advantages of OHP lecturing are similar. Therefore, the proper use of a projector for lecturing must be understood[110,128].

Projector supported lecturing

Overhead projection of lecturing material has a number of advantages over prior methods of lecturing. For instance, it has all the same features of the blackboard with the exception that it can be prepared beforehand. Experimental results which may take time to write on a blackboard can be written in advance. This ensures that essential material is not omitted. Furthermore, because the slides are portable and generally owned by the lecturer, they can be re-used. In contrast a blackboard does not require a power supply and low lighting.

However, in addition to the benefits, OHP lecturing brings with it problems. For example, the users of OHPs must consider the amount of information on each slide and the size of the written text. If they speak too quickly or stray from the information on the slide the audience will become confused. The audiences' focus of attention may stray if the lecturer does not position the slide correctly and point out the relationship between the narrative and the slide. Finally, the light during many projection-based lectures might need to be dim and would thus lower the students' levels of arousal[130]. This latter point appears particularly so when employing 35mm slides.

In order to present information written on the overhead foils correctly extra operations are required of the presenter[128]. Current OHP style lecturing operations include hiding, revealing, pointing and highlighting. In addition to these the lecturer may still utilize the blackboard (available in most lecture theatres) to accentuate the examples being discussed in the lecture. The slides could be modified by the lecturer whenever necessary and several techniques such as overlaying slides can be used to introduce new illustrations or make complex modifications to diagrams.

• *Operations of projector lecturing*

During a lecture it is often necessary to draw attention to particular details of the slide images. Generally the presenter will use a pen or pointer to indicate currently relevant details. Alternatively a piece of paper can be used to cover information that is currently unnecessary. These indicators can slip and so misdirect the audience. Extra embellishment can be made in the narrative to highlight the point definitely but this time could be used more profitably in a short presentation.

To avoid this problem it is possible to have each new point individually highlighted on new slides. With OHP, the new slide is overlaid on the old slide. With a 35mm slide projector an entirely new slide can be displayed. This can cause confusion too because changing slides do not immediately give an indication of what is new information. The audience may not be sure whether this slide is totally new information or just has additional information to the previous slide (Figure 5.1).

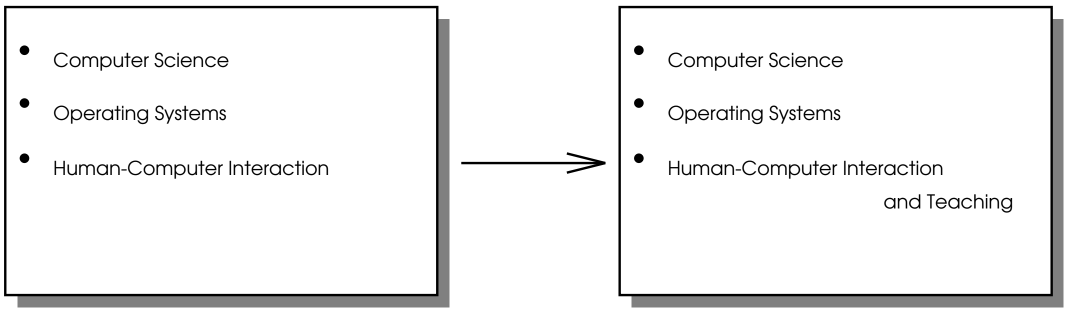


Figure 5.1: An example of minor slide changes

The original technique did not have this problem since the visual cue of pen or paper moving identifies clearly any new information. In a digitally stored lecture, visually animating the revelation (moving a pointer or cover-up) may overcome both slipping pointers and confusing revelations.

• *Further preparations*

Some lecturers prepare copious notes beforehand and some recount a narrative on tape. They make use of tape-controlled slide projectors which playback the pre-recorded narrative and control the rate that slides are selected. Using tape will help to ensure that the narrative is well prepared and does not rely on the recall of the lecturer. Even though preparing the tape is very time-consuming, for a lecture which changes infrequently the overall saving of pre-recorded narration can be great[131].

With slides that are carefully prepared and loaded into a slide projector controlled by audio tape, the lecturer loses some of that ability to generate new slides on-the-fly. Modifications to the order of the material becomes impossible once the presentation begins. This means that a great deal of attention must be paid to the durability of the material before it is produced. Changes in the form of insertions and deletions will take time and extra effort to produce well. Particularly since the lecturer's voice may change over time.

5.2 On-Line Lecturing

It has already been seen that multiple media can be reproduced with IT, but this should not be the focus. Increasing importance should be placed upon the narrative structure of a presentation. This section will examine the presentation of a lecture rather than the content. Focusing on content production will not discover how to make the best use of IT media. IT is ideally suited to automation.

5.2.1 Automating Presentations

The main problem with traditional lecturing which might be overcome with information technology is the ability to record and replay the lecture effectively. Recording the presentation will allow students to self-study the content and thus attribute additional understanding to their notes. Video recording the lecture is not a solution because the lecture will contain unnecessary pauses and errors which could be otherwise removed. The editing and distribution of digital video recordings is now more viable than with analogue video material. Yet, digitally encoding the material makes heavy demands of computing resources and does not overcome the problem that the course must be re-recorded (onto video tape) in its entirety each time the lecture content changes. Video also needs experienced people to carry out the recording and to edit the video.

The alternative is to record the lecture components (text, video, narrative) separately in manipulable forms and automate the order of presentation. Displaying the conceptual parts of a presentation on a computer can be achieved in two ways: automatically and programmed.

i) PowerPoint[107] automates presentations by marking items with a tag of some type. These might be to mark title text, bulleted text or a diagram. The display system will show each new title, bullet point and diagram from top to bottom on each slide. These are inflexible for any presentation which does not follow this scheme. To achieve more flexibility the structure can be expanded. In Toolbook[68] this requires graphical objects to be linked with other objects on the slide. For example, each slide is connected to some heading text. The system tells the slide to appear and it will tell its children to appear (e.g. bulleted text or heading). Once all the children of all elements in this slide have been executed, the slide will pass control to the next slide. This process is computationally orientated and so it is flexible and generalised.

ii) Alternatively, programming instructions can be embedded within the body of the lecture such as those provided by SGML. The Standard Generalised Markup Language (SGML) is useful for documents because it can annotate the content of a standard ASCII text file in a sensible way. It is the basis of the more common HTML language used for page creation on the World Wide Web. The author marks bulleted text, titles, images and so on according to this portable scheme. The way a displayer represents the document is decided upon locally and not defined by the scheme itself. This could allow the lecture content to become widely distributed and not be reliant upon the presentation tool that was used when the lecture was designed. In the future, better presentation tools could appear and the old content could be re-used easily. Unfortunately, older courseware and traditionally authored lectures must be converted into a form for SGML. Drawings need to be made into images, for instance. Once this is done, the content should never require modifying unless new technologies are to be used. The content will remain backwardly compatible.

The authoring facilities for both of these mechanisms must attempt to be natural to use and not assume any previous experience of the user. By identifying the specific needs of the lecturer who must be able to create slides quickly and easily, it should be possible to design a system which will not leave the user frustrated by the interface or bewildered by manuals.

Further to the recording of on-line lectures, on-line editing is also a problem. The slides themselves can be difficult to modify on-the-fly but if the presenter has access to a mouse during the on-line lecture, most systems allow them to annotate using line drawings. A keyboard can allow the addition of typewritten text. However, in a similar respect to OHP presentations, the text cannot be modified invisibly. In contrast, the blackboard lecturer might simply alter the text in mind before writing it on the board. Should a lecturer wish to re-order slides once the automatic presentation has begun they will usually find difficulties (as with 35mm slides). This is not the case with traditional OHP presentations. This leaves the lecturer no control over the presentation except through that which was originally authored.

A number of good systems have been suggested for giving lecturers the ability to manage the live presentations on-line[132]. They involve two or more screens, one which only the lecturer sees and the others which can be seen by the students. The lecturer decides what should be seen next and then sends only this data to the student's screen. Although this solves the problems of rigid lecture presentations, they may be difficult to use for a novice lecturer. Some recent developments have produced a fully usable system that enables modifiable live lecture presentations via a computer[96]. In the future, the lecturer's actions to give this presentation could be recorded along with the narrative. The system could then replay these actions automatically for a student at a later date.

In addition to the construction of on-line lectures, the environment used to present OLLs holds other benefits and problems. Students have always be able to make use of presentations for private study yet no direct support for extended learning has been available. That is, the student is learning through the lecture purely as a passive medium. Experiments, for instance, could also be used to demonstrate the correct application of concepts; yet this is not so important at the lectured stage of learning. Annotation is usually all that is required. On-line lectures must exist within the environment of traditional lectures. They can exist as 'canned' lectures which may or may not be supported with a lecturer. A lecturer will be able to annotate the presentation in response to student activity and feedback.

5.2.2 On-Line Lecturing Requirements

By considering all of the beneficial and problematic features that have been proposed of OHP and on-line lecturing (OLL), in terms of the reader's and author's needs and the operations applicable to the media, it will be shown that it is possible to produce a system with sufficiently useful features to meet the needs of university education. Thus the focus is upon the dialogue and the media usage.

Providing extensive functionality is not always desirable. For example, a lecturer may want to edit all aspects of a presentation on-the-fly but the lack of this capability may actually force the preparation to be more thorough. Even if this were not the case, since good and bad presentations really depend on how the author 'uses' the media rather than the media itself, the flexibility of a system is not the issue. Too much flexibility definitely increases the complexity of interaction so it is argued that the flexibility should be limited.

The benefits and problems that have arisen through looking at the authoring tasks and the learning needs must be weighed up against the facilities which the computer as a medium has to offer (Figure 5.2). Thus the system requirements are viewed in terms of what the learner and author need and do not need. This will indicate how the media should be used by the lecturer to benefit the educational environment.

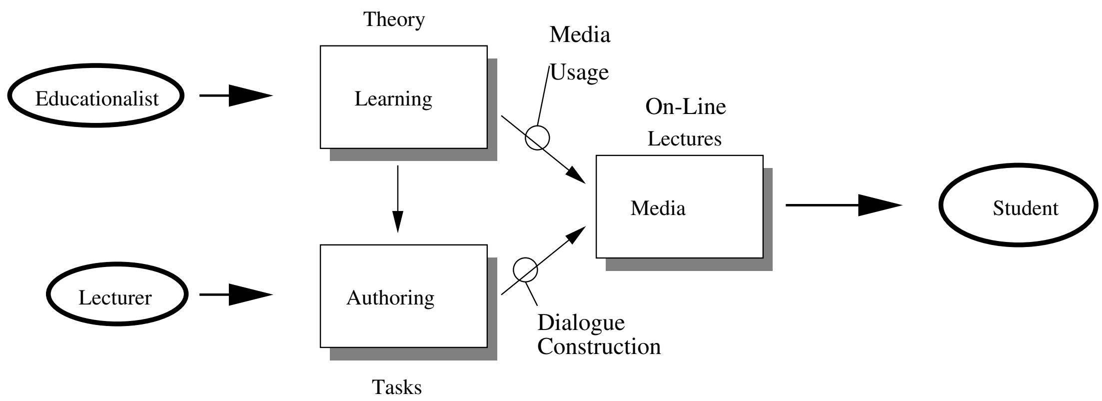


Figure 5.2: Media offers for learning and authoring OLL

Learners — Firstly the presentation medium should allow for the presentation to run automatically. Each slide in an automatic presentation should contain a sound argument or new piece of information. In addition to the written text, it is important for an appropriate delay to be present at the end and start of each slide, to indicate closure of that slide and the start of the next.

An advantage of having the material on-line is that it permits private study. This enables the student to go over what might not have been understood during the lecture period. It also enables students who miss lectures, for whatever reason, to catch up with the course at some other time. It might certainly be possible to do away with timetabled lecturing altogether and merely have problem classes where the lecturer can go over work that may have been misunderstood. For private study the students may also receive a collection of lecture notes. Interaction during this study should not hide the content or presentation. Hence a simple and familiar mechanism for pausing the presentation and reviewing material will be the only requirement. A break in the presentation is not purely to ask the viewer a question or give the opportunity to play with a simulation. This extra activity needs authoring and makes the production more complex. The student must have the means to repeat and cogitate over material.

In contrast, there are suggested requirements which, if omitted, would not hinder a learner during a presentation. For instance, one of the important benefits of an OLL system is that the material is planned and pre-recorded. It may seem appropriate to help the student with live annotation during an on-line lecture but this will affect the original plan. Any material added during a live lecture will not appear when the material is played back later. If this additional material is to be made available then it might be added to the pre-recorded lecture only after further deliberation by the author.

In a lecture it is often useful to demonstrate a real system via a simulator or by using the actual application. The integration of this into the OLL means that the material is also available for private study through the system. However it might be better to keep these separate in order to distinguish between the practical aspect and the preparation of its use through course material. The demonstration can still be used but there is no need for it to be incorporated in the OLL. In a similar respect, the lecturer might want to have moving images which are controlled through the system. The extra authoring required to incorporate these into a lecture may not be worth the effort considering the amount of learning outcome gained. Either a more abstract or diagrammatically static picture would explain the point better or a physical demonstration would produce a better transfer of knowledge.

Authors — For a teacher authoring a course, there are important benefits which support the construction of presentations. Basic content construction facilities such as text and graphics should be simple to use. They should adopt a mechanism which does not require complex interactive dialogues. Furthermore if other media such as animated graphics, sound or speech are to be used, these should similarly be easy to author.

Because the lecturer will require facilities for constructing the order of presentation, mechanisms for specifying this should be as simple as specifying the content. The simplest top-to-bottom revelation of the content will be most commonly used and thus should remain the easiest to author. Reviewing material that has been covered and previewing that to come is important in lectures. The timing of revelation of material which is generated automatically might also require enhancement and so additional pauses to those which are automatically inserted may be required.

There are facilities which, if omitted, would not harm the quality of construction. It is not uncommon for video to be recorded and played back during lectures. The danger with video and audio is using it inappropriately and wanting to generate video and audio productions which have only one use. These are very difficult to author quickly. For every-day lecturing, text, simple diagrams and captured pictures are all that are required.

When a system uses colour it is extremely important that it is not overused or used incorrectly. Even though colour is attractive the author needs an understanding of graphic design or art to use it successfully. Contrasting colours and faint or dark colours will be difficult for all students to view and may hinder a student with colour deficient eyesight. Similarly the inclusion of many typefaces will give an author too many options and divert them from developing the content. It is important that they are capable of selecting appropriately sized fonts for the lecture theatre presentation.

Hypermedia is an important and valuable addition to educational technology but it does not solve all problems. In a lecture environment the material is being transferred quickly and succinctly to a passive audience. Thus the ability to author hypermedia links is not a valuable asset. The lecturer does not wish to have to remember the correct forward and backward links in order to move correctly through the material. If the plan has been prepared, why does the lecturer need the opportunity to change it? This relates to problems of trying to author material live. Linking material to simulators and live applications again requires the lecturer to consider carefully the plan in order to transfer correct information to a student. Generally lectures are not the forum for practical experience.

In summary, the viewers of lecture presentations need to be able to move through the material as the author intended but with the opportunity to pause and reflect. The authors need to create quickly the content of a presentation utilising familiar media tools. Finally, they must be able to develop and implement a plan of the exposition of the content in an intuitive manner.

5.3 On-Line Lecture Implementation

The on-line lecture (OLL) concept[1] has been implemented using the Book Emulator[5,133]. Not employed by this system are hierarchies of menus, pop-up dialogues, shortcut key sequences and modes of working since they may confuse or hinder the inexperienced user[16]. In fact, no prior computing experience is required from the user. The mouse is used simply to point, pick up and drop down schematics in a virtual manner onto slides in a book. This is an attempt to provide a simple method of construction which will not burden the lecturer. There are two users of lectures, the active authors and the passive readers and both need their own electronic books. One book is for the construction of on-line lectures, and the other for their presentation on-line. The author will generally control the presentation book during the live lecture but this is not a requirement; a locum teacher or a student could activate and control the presentation.

5.3.1 Construction Method

Drawing from developments and research in HCI many designers of educational authoring systems have adopted strategies such as object orientation (O.O.). This means treating all graphical icons, text, and so on as objects which can be manipulated. This enables authors to move and position objects independently of their physical representation on the computer screen. The construction mechanism used in the OLL system is schematic object based and simply allows elements of layout and specification to be manipulated.

However, in following the O.O. metaphor to its conclusion, some other authoring systems[67,68] have provided facilities for programming objects in a way which is similar a programming paradigm. To a lecturer, message passing and inheritance facilities, must be entirely alien to their way of working but CAL designers might argue for flexibility. By authoring buttons the lecturer can define their own interaction with the system during presentations. Often buttons for travelling through the document are placed inappropriately and make use of language which only the author can reasonably understand. Common navigation requirements might even be omitted (e.g. going back a page). Figure 5.3 shows the kind of situation which may occur.

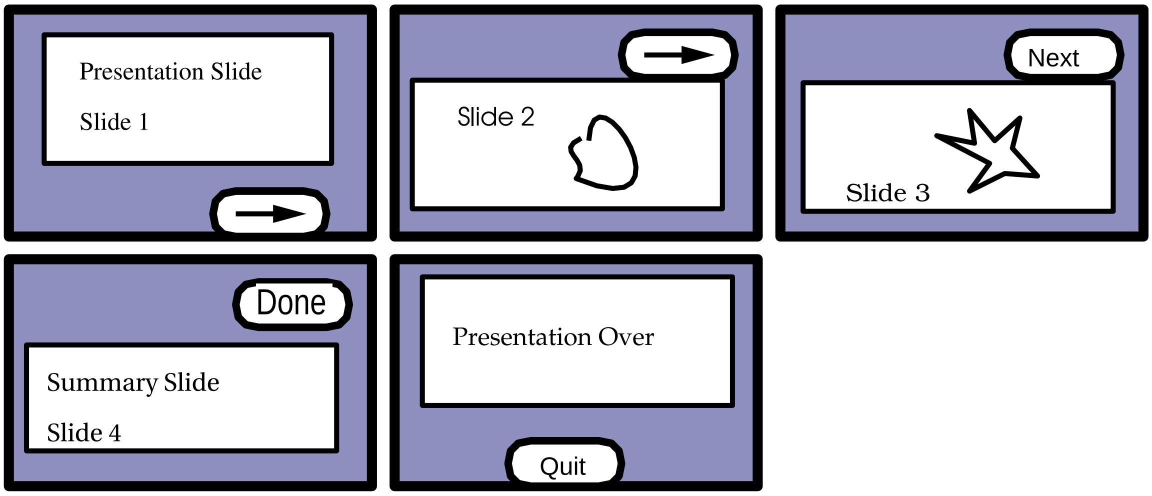


Figure 5.3: Inconsistent presentation layout

It is extremely important that some form of continuity is maintained in the interaction during a presentation, and especially if the student is to use the material for private study.

Having realised that programming is a problem, designers have generated default scripts for the common presentation travel-buttons and other objects. This reduces flexibility but enables many lecturers to ignore the programming facilities completely. Alternatively they generate templates[107] for each slide so that a common interactive theme can be maintained. This again has reduced flexibility by fixing functionality. Buttons are no longer placed by the author and only an ordering of presentation is needed.

It has been argued in this chapter that only two main aspects of lecture production are required in a computer based system; the content itself and its automated presentation. Attempts at incorporating flexibility in the interaction with the presentation will ultimately fail due to the need for rapid production. Lecturers cannot learn to construct lectures rapidly when presented with a large variety of flexible functions for automation. Functions for marking up the substance behind automatic disclosure are needed. Automatic disclosure being to show points created on a slide one after the other and each slide being shown in order without lecturer intervention.

Therefore, in constructing a lecture or slide show, the layout of each slide is defined using the normal facilities available in the Book Emulator for page layout. A double page spread is used to represent each slide within the lecture *construction* book. This book is constructed from two types of slide: *layout* and *specification* slides (Figure 5.4).

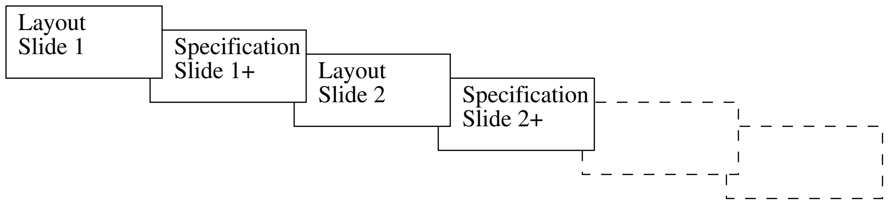


Figure 5.4: Layout and specification slides

Each layout slide represents that which the reader will view and the specification slide that immediately follows the layout slide in the book describes how that layout will be presented.

5.3.2 OLL Slide Layout

The layout slide shows only the information which the student will see and can be created by the lecturer without concern for any particular presentation sequence. Although the media which a computer can emulate are numerous only a handful can be easily authored using current methods. Text can be written, diagrams can be sketched or imported, and modifications to diagrams and text can be prepared. Audio can be recorded for narratives but this takes time.

For slide layout in the Book Emulator, a selection of text fonts, and some simple schematics (boxes, arrows, mathematical symbols) are compiled into library books available for both lecture construction and other such on-line books (Figure 5.5). Each symbol's use is described in these books to instruct the novice user and to remind the experienced user.

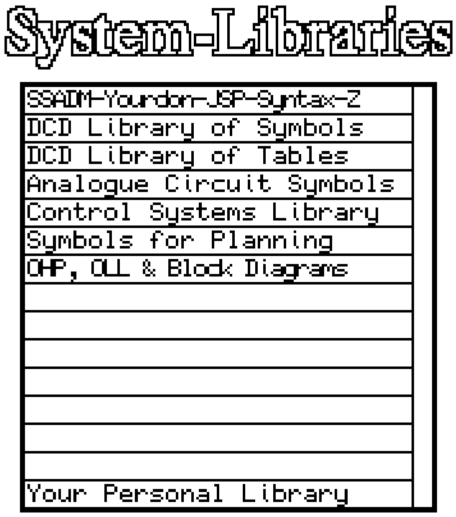


Figure 5.5: Library book selection

Ingredients available in these libraries for slide layout include:

- Text - A variety of fonts are accessible in many of the library books. The user picks a font and then types the required text which appears at the mouse cursor. This text is effectively a schematic which can be dropped or picked up in the same way as any other. In addition, it is editable once picked up. Large characters are provided in the OHP/OLL library books to ensure that the display is visible in the lecture theatre (Figure 5.6). Each schematic represents a stencil which can be selected. However, the keyboard is used to draw out the text rather than tracing each character as with a normal stencil. Once drawn, the text can be positioned and fixed to a page.

Figure 5.6: Some text fonts for slide layout

- Graphics - Bitmaps of diagrams can be placed anywhere on the slide. The diagrams are selected from the library of symbols or from a personal library of schematics created using Drawing Board[134]. A standard feature of the Book Emulator is the rubberband line. The user can select this and stretch out a straight line between two fixed points. The line can be moved, as can the two fixed points, if desired later.

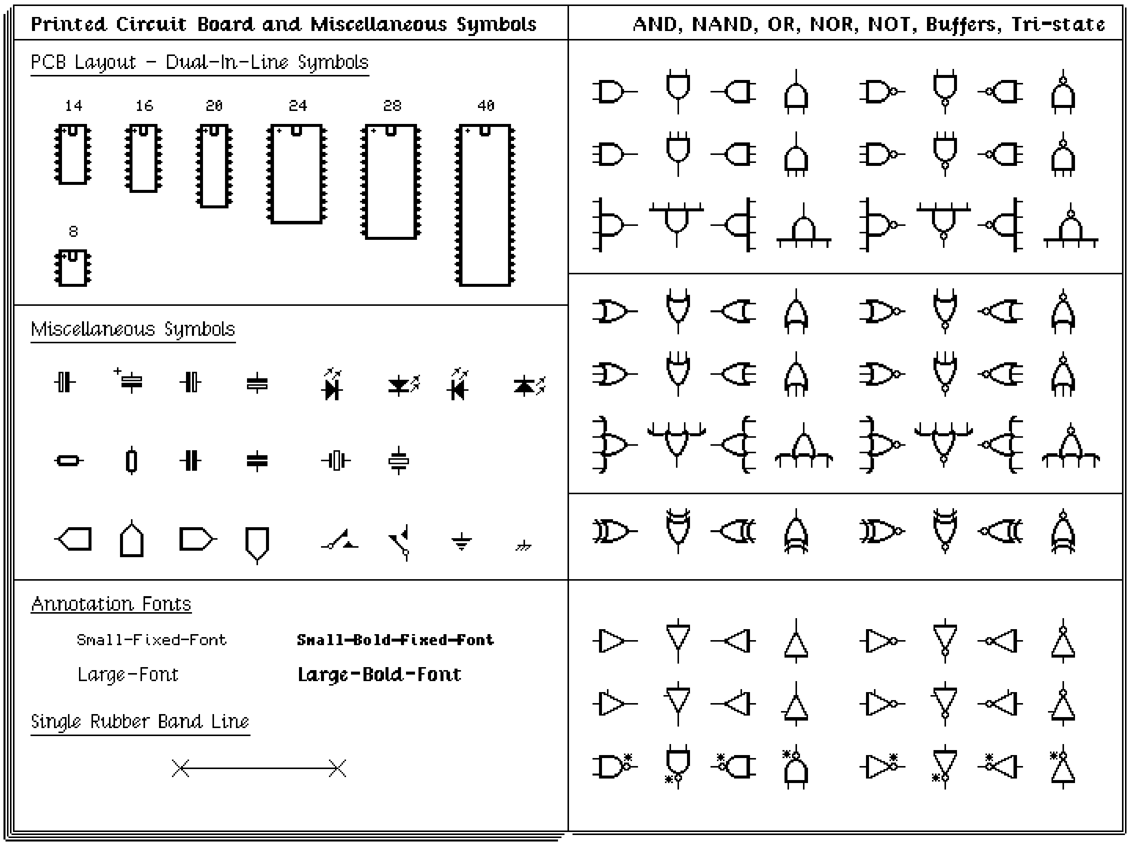


Figure 5.7: Some schematic symbols for slide layout

- Diagrammatic animation - Sequences of bitmaps such as digitised video can be placed on the slide. The animated symbol, which will be shown to the reader, is placed on the layout. When that section of the slide is viewed, the animation will begin according to its specification. This symbol is taken from a library of animated symbols. The library is constructed from a book for editing animation. †

- Audio - Although audio is conceptually part of the layout it is not seen by the user. The time when the audio is heard needs specifying along with the item of audio to be heard. However it is authored like content which should, in theory, appear on the layout. Even though this is the case, it makes sense to place the audio identifier and the time to play the audio on the specification slide. This means that the layout slide is not cluttered with visual identifiers of audio and timing information.

† At the time of writing the animation creation book was not available, yet ready-made animations can be positioned on a layout.

An example

The layout in figure 5.8 is designed to show all the ingredients. It is falsely complex, and a lecturer might not normally have all these ingredients on one slide The author has selected a font from the library book which has enabled text to be typed and placed. The box was taken from the same library book as contained the electronic symbols. The image is the first frame of a digitally captured video animation. Notice that no audio content is visible although it may be laid out on the specification.

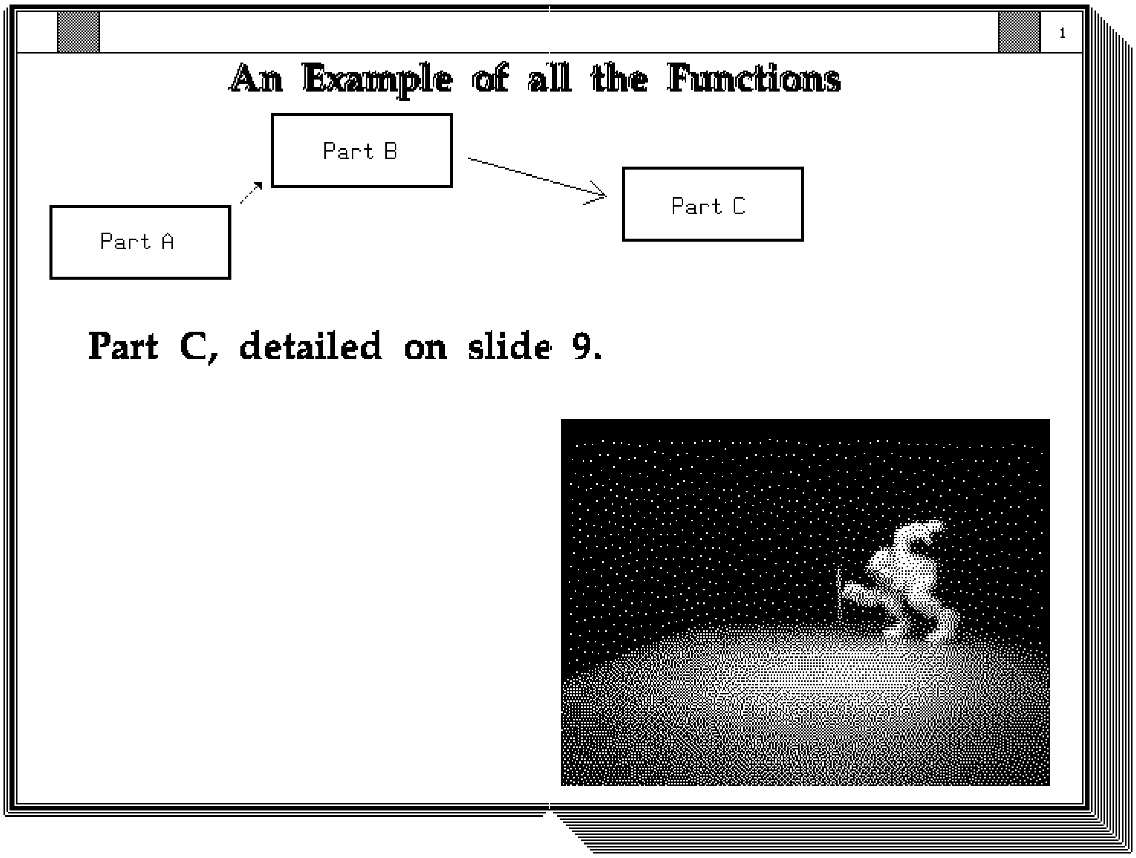


Figure 5.8: An example layout slide

5.3.3 OLL Slide Specification

The specification slide visually "programs" the sequence of revelation by the placement of concise and comprehensive symbols[115]. This specification slide is associated to the layout slide by following it immediately in the book. If the specification slide is left blank then the information on the layout slide will be presented in its entirety during presentation.

For slide presentation specification, the "programming" symbols are listed within the construction book itself. This is because they only make sense in this book. Although it is feasible to have the symbols on each slide it is not practical. The symbols would have been cluttered and the help text surrounding the symbols would have to be accessed though another function. They can be found near the beginning of the book so an author can easily locate them. A button is available to allow a user to jump between the current specification slide and the double page of symbols (Figure 5.9). A bookmark is placed on the current specification slide to enable the author to return to their work once a specification symbol has been selected.

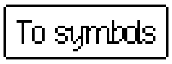


Figure 5.9: Button to jump to specification symbols

Specification operations come in two categories: the specification of **revelation** and the specification of **advanced layout** (Figure 5.10).

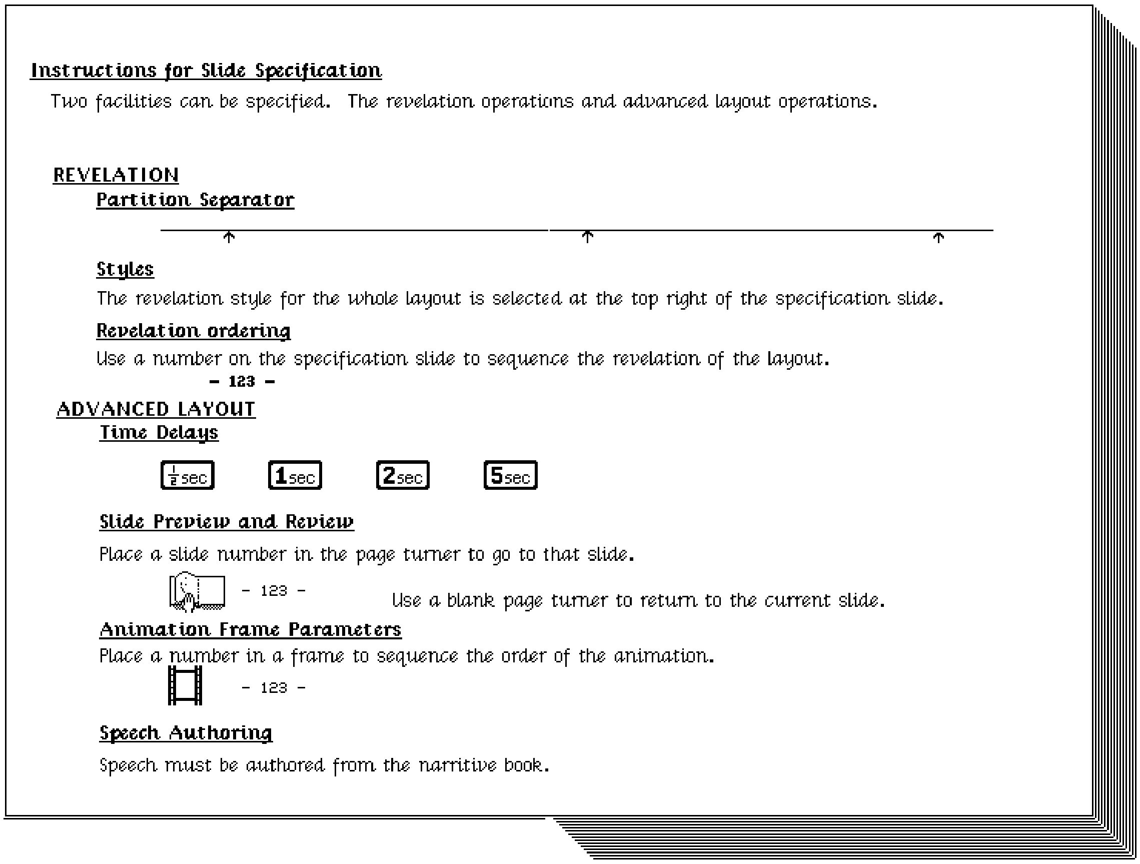


Figure 5.10: Operation symbols for specification

Revelations

Some "programming" symbols enable the layout slide to be partitioned so that certain parts of the slide can be emphasized in a sequence.

- Partition separator - Rule-offs can be positioned at any point on the slide as needed, but they will be processed in an intuitive top-to-bottom order. In contrast to other presentation systems, this technique seems more natural. For example, Powerpoint and Toolbook[68,107] might have had the user select text items using a dragged rectangle. Then all the items with this rectangle's boundary are grouped and marked for revelation. All these groups would then be automatically or manually sorted for revelation.

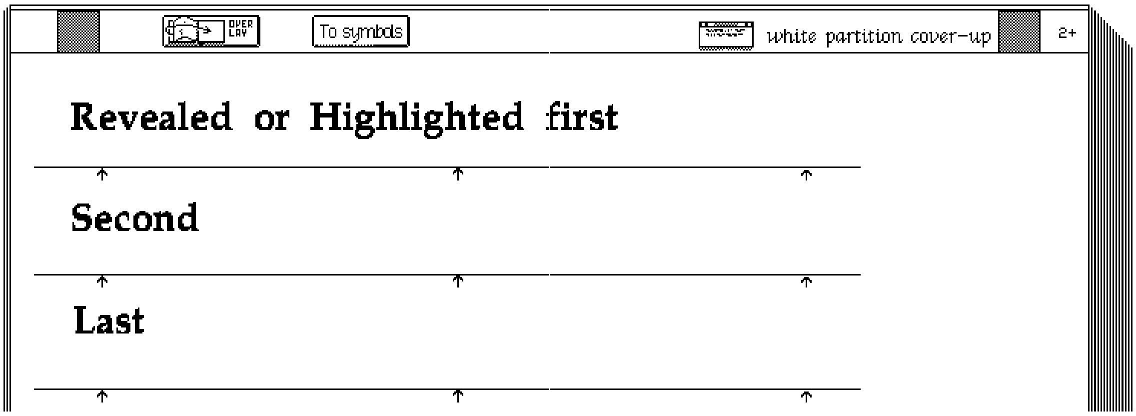


Figure 5.11: Processing order of sequencing

- Styles - Emphasis is achieved by covering up or fading non-important information, or by highlighting the important information. The selector for this is on each slide since it is applicable to the whole slide. It also acts as a reminder to the author as to which style will be used.

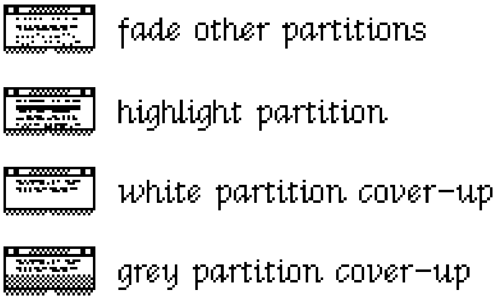


Figure 5.12: Four types of slide revelation

- Revelation ordering - The schematics on the layout slide can be revealed in a non-sequential order, if required. This is achieved by placing a number on the specification slide in the same area as the schematic diagram on the layout slide. The overlaying facility (see later) is useful for ensuring correct alignment. That schematic symbol will be displayed during the presentation at the same time as other symbols with that number. The numbered items will be displayed in numerical order before any unnumbered items. Additionally this mechanism can be used to re-order the advanced layout.

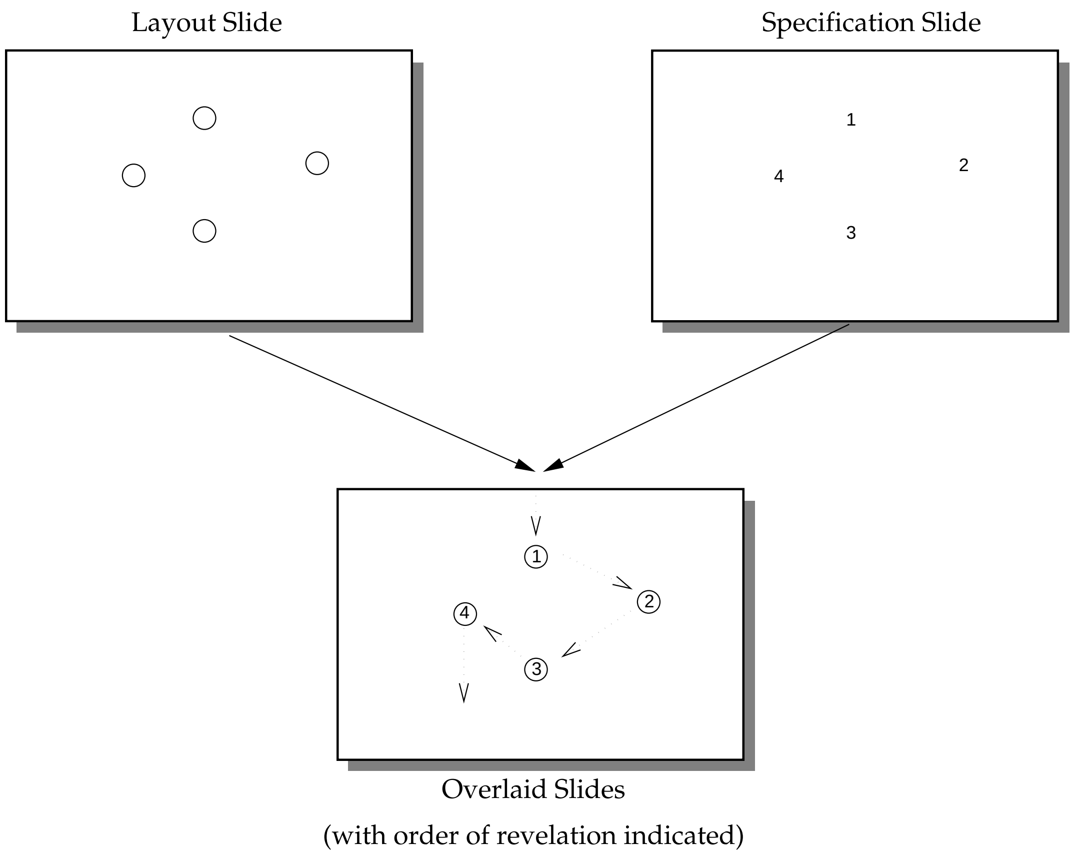


Figure 5.13: Content animation

Advanced Layout

Advanced elements of the layout can be authored on the specification slide. These elements are *operations* such as playback of narrative speech bites, frame selectors, time delays and slide previews and reviews. These operations are carried out in an intuitive sequence and discretely within each specified partition of the layout. Thus, each partitioned area can be "programmed" to activate certain operations.

The intuitive sequence in which the rule-off lines and symbols within the partitions are activated is naturally left-to-right then top-to-bottom. This is in keeping with the expectations of the lecturer and reduces the overhead of maintaining a specified ordering.

The ability to attend to more than one sensory channel (auditory, visual, haptic, for example) at the same time is difficult; the focus of attention needs to be switched between them[1]. Discretely presenting speech, highlighted information and animation ensures that the observer's attention is focused. Additionally the technical difficulties of synchronizing audio and video makes it unfeasible to author.

- Time Delays - To give students time to think about material displayed it is possible to specify delays in the presentation. However there are dangers of wrongly associating information that follows if lecturers use this incorrectly.

- Page Previews and Reviews - Previewing slides (with page-turner markers) that may come later is useful for introducing material. Reviewing slides is similar but for re-using diagrams that may have already been seen. Since the slides are numbered and in a linear order the viewer will know where the previewed/reviewed information exists in the presentation without confusion.

- Animation Frame Parameters - The content of the slides can be animated in two ways: a fixed form on the layout, for example when including animated bitmaps; and a form which slowly reveals the layout, for example when highlighting particular points that do not follow the natural sequential order (q.v). Animated bitmaps are initially shown on the layout page. The animation comes in the form of subsequent frames which are selected on the specification slide. The order of the animation is dependent on the order of the frame selection that has been specified.

  Currently only one animation can be specified within a particular partition because the frame numbers represent any frame with that number in the partition.

- Speech Authoring - Bites of speech are created in a speech capture book. All the speech bites for a lecture are collected in a narration book associated with the constructed lecture.

An example

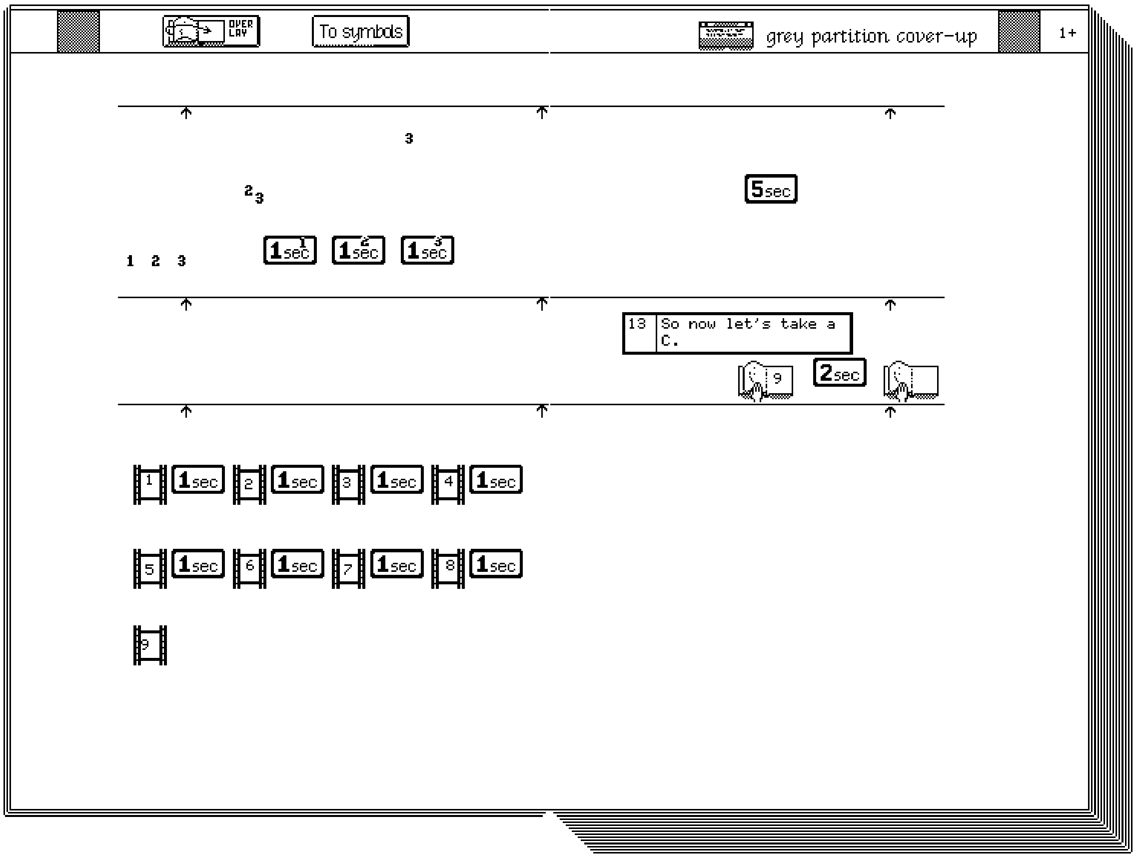


Figure 5.14: An example specification slide for figure 5.8

The *specification slide* (the *layout slide* was given in figure 5.8) has been partitioned for displaying with grey cover-ups. Each slide is partitioned by the placement of a dividing (rule-off) line that is provided as a schematic symbol in the library of visual programming symbols.

Because of the nature of separation of specification and layout, it is necessary to have some facility to bring these two together. Therefore, the specification slide can be overlaid with the layout slide. This allows for better alignment of the rule-off lines and other symbols. This could have been a default action but it can look cluttered (Figure 5.16) so it has been made optional.

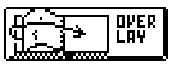


Figure 5.15: Button used to overlay layout slide onto specification slide

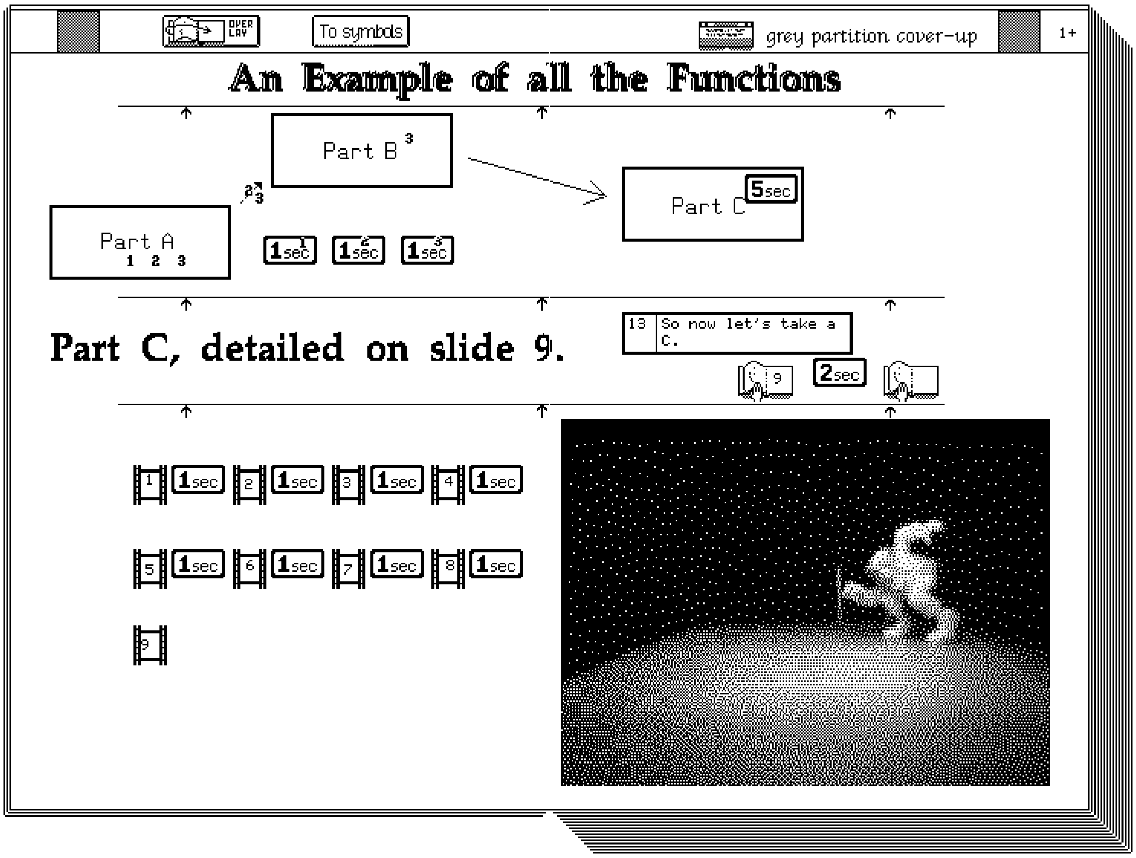


Figure 5.16: An example of overlaying

5.3.4 Presentation Method

In most OLL systems the material is shown slide after slide as the lecturer clicks a mouse button or presses the space-bar on the keyboard. This can be further decomposed into displaying the bulleted points one by one at each mouse click. This is simple but does not give the presenter a simple method of reviewing the material. Reviewing material by stepping backwards is very useful for students during private study.

In addition, during private use a reader (a student or another lecturer) may wish to make annotations and question the material. Thus a few additional interactions are often considered necessary during learning. However, feedback and interactive discovery learning is best suited to another metaphor and the OLL design does not become trapped in an attempt to satisfy all the learning needs. The system here is intended to be familiar and mainly support public tuition and pre-requisite learning.

Lecturer

After the lecture slides have been constructed they are compiled into a *displayer* book which is used for displaying the on-line lecture. The method for displaying the lecture is simply a stepping through of the slides as if manipulating a slide projector. It is also possible to have no interaction with the displayer at all by leaving the presentation running step after step in a continuous-play mode. Delays are automatically inserted before a new partition is begun and at the end of each slide. The displayer can be stopped and restarted during a continuous run. In a lecture this allows questions to be asked and points can be repeated if necessary. In single-step and continuous mode the facility to repeat sections is always available, merely by going to the correct slide and playing though its partitions again.

Notice that this gives the lecturer an exact and familiar OHP style of system which does not require much learning. There are no facilities for dynamically interacting with the presentation, perhaps to modify the text or reposition a diagram. Nevertheless the inherent facilities of the Book Emulator allow slides to be recalled locally and information overlaid as required. This is purely for annotative purposes and is not intended to be used regularly.

Figure 5.17: Presenter travel buttons

To stop the presenter once it has begun, in order to play the whole sequence or one of the partitions the lecturer needs only press a mouse button. This button press will interrupt the playback at this point. Replaying the sequence will start at the beginning of the interrupted partition.

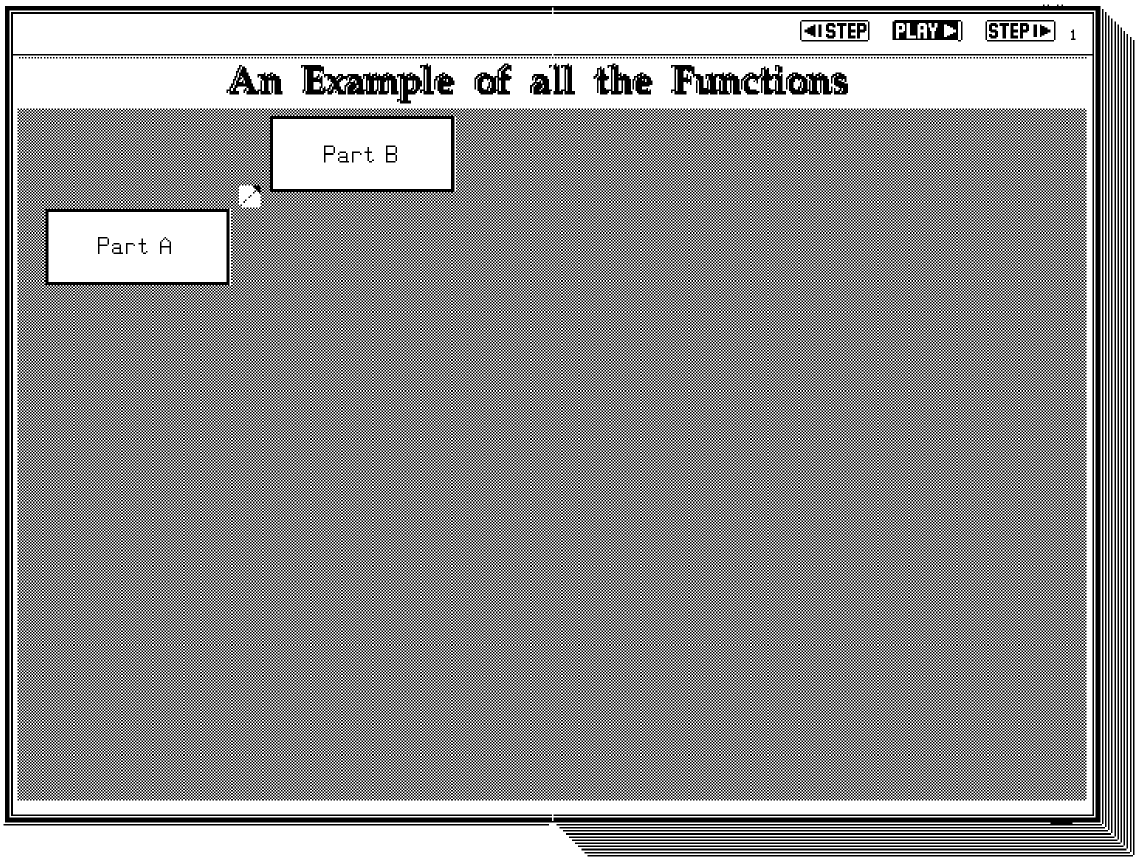


Figure 5.18: Displaying the slides

One possibility which would increase the Presenter's similarity to a slide projector is to link physically a slide projector controller to the forward and backward stepping mechanism. This would make travel through the slides in a live lecture more natural for the lecturer. Alternatively the three mouse buttons could be used to represent these actions. Unfortunately, the Book Emulator cannot be programmed to allow the mouse buttons to represent actions other than turn pages forwards, turn pages backwards and select the item currently below the cursor. Nevertheless, doing this would fundamentally alter the way in which the Book Emulator works. It would increase cognitive load on a user and introduce modality. The user would have to select ordinary mode and live-lecture mode for the mouse. Instead, the travel buttons on the slide are selected to step forwards and backwards through the partitions of the slides.

Student

Once the material has been compiled it can be made available to students before or after the lecture is given. This will enable them to study it at their leisure. They have access to the same controls as a lecturer. The Book Emulator provides facilities for making textual and graphical annotations which are local to each student. The content of the book will not be alterable by the student except through the annotations which they have made themselves. This will help a lecturer to work with an individual student at a later date because the lecturer can be given access to these annotations.

5.4 Commentary

Mechanism

A complete on-line lecturing system has advantages for both the lecturer and the student. The lecturer has a distributable means of generating courseware material that can automatically give 'perfect' lectures. Being distributable it gives the student a form of electronic 'hand-out' that can accurately reproduce all the information given in a lecture. The lecture period is not the only place where the student can gain their first insight of curriculum topics. With ready-made lectures, when the lecturer is unavailable (through illness, for example) an alternative lecturer can give it. The original lecturer will still know what material has been covered in each lecture and students will not receive inconsistent work.

The lecturer does not lose any control over the course content, hence their responsibility and professional status remains intact. This may be one contributory factor to the lack of use of information technology in the past. By making the best use of the technology, academics have more time to spend on their own research (which benefits their institution), and on tackling student misconceptions. With a familiar metaphor, lecturers are able to use computers; it is a step towards "CAL into the mainstream."[135] To this end, the schematic style of slide production has been chosen to be simpler for lecturers to use than many other highly functional and highly complex graphics presentation systems. The visual programming style of authoring also protects the user from the difficult syntax and semantics of scripting languages.

The problem of physically narrating the course could be alleviated by using text-to-speech systems[136] which can add a variety of voices to the presentation. It could be made possible to record and transcribe the activities of the lecture (e.g. notes made directly to the book pages by the lecturer) so that subsequent presentations may benefit from the information[95,96].

It is often impossible for students to make their own annotations to their own copies of lecture material in other OLL systems. The alternative could be to add a link to a window containing the annotation, but this is not a good method for browsing. By using the Book Emulator the student has access to the normal facilities it provides. The Book Emulator is simple and intuitive to use and does not require the student to waste valuable time becoming accustomed to windows, menus, and dialogue characteristics of other OLL presenters. First time and novice student users will resist using an on-line lecture system if this is the case. They will also not be making the best use of their time at the computer.

Media Usage

Each lecture is conveyed through a book of slides, the material being presented with or without traditional cover-ups. Being on-line, difficult parts can be repeated time and time again until the concept is understood. The strict adherence to a book metaphor[5] ensures that students can dip in and out of the material in a non-linear fashion as they would do with a real book. Yet they are always able to see how one topic builds on that of previous topics because of the inherent linearity of the material. The advantage that this computer-based teaching system has over traditional paper-based teaching is that the narrative and presentation method is preserved. The student will get more clues from these media than purely written text.

Facilities for the student to send annotations to the lecturer could be implemented, so that subsequent lectures could benefit. The student can use this facility to point out their own misconceptions about the courseware for clarification by the lecturer. The lecturer could respond by making notes in the student's copy of the lecture material[99], thus combining private learning with tutorial supervision. Group learning activities could be achieved since discussion about topics via the computer network can be based on visible and distributed course material from the privacy of the student's terminal.

However, the disadvantages inherent in all lectures will also be emulated and so the OLL system adds nothing other than its simplicity of use. The learner can work at their own pace and go over material that was not understood the first time the lecture was given. This contrasts with the live lectures given once a year. The amount of repetition and level of note taking possible in a lecture may improve the students' performances[45]. In addition, a physically disabled student would not be restricted from lectures in inaccessible locations. For the student who desires information and not tuition there is no advantage over other CBE text and data retrieval systems.

Future directions are to improve the interaction so that students can request related information about any course material they are finding difficult. For example, the course textbook could be on-line to supplement the lecture notes. Other textbooks and other courses which have similar themes can be automatically suggested for exploration.

Chapter 6

Argumentative Based Learning

It has been argued that students must be able to learn passively and actively. OLL passively presents information but lacks interaction. Later some kind of feedback and interaction is necessary, and this can be achieved by active engagement with the material.

Students who seek out the underlying concepts and understanding behind knowledge consolidate their learning. Those that are able to verbalise and justify their consolidated reasoning, will learn more thoroughly. The action of seeking and justifying enables students to take control of their learning, which is very important if they are going to feel motivated towards learning. It is support for these characteristics which is the essence of the CBE technique that is described in this chapter.

Learning through the act of arguing will be examined as an engaging educational dialogue for clarifying and consolidating understanding. By ensuring that students can make critical assessments of what they know and what others are presenting to them, the teacher will be developing the learner's ability to think. Achieving argumentation via teacher authored courseware has never been attempted before in a CBE environment. Yet Bligh[137] presents methods of using discussion to teach thinking. Recently Hammond and Reader[120] have considered that argumentation might be used for helping students to fit together pieces of understanding. The computer will provide a new forum for this discussion within topics. This forum can be at both the student's and the teacher's convenience and also be distant from the university.

This chapter is divided into two main sections. The first section describes the theoretical aspects of designing an argumentative system which aids student learning. The second section describes the implementation details that embody these theories.

6.1 Computer-Based Deep Learning

A key aspect of this thesis is the attempt to improve a student's deeper understanding of course material. This deeper understanding must result from using a computer system for learning so that major benefits from automation can be gained. Rather than approaching a solution directly from educational psychology to instructional design, this chapter will begin by defining how the areas of the model devised in chapter 4 can be satisfied. This requires an educational medium which can convey a computer-based teaching dialogue.

After the model has been satisfied, the second section describes this novel method for computerised learning that stems from demonstrative tuition by having students actively engage in their own learning. Guidance will be "over-the-shoulder" in concept and be familiar to the student.

Finally, the teacher's requirements when developing course material for the demonstrator system are explained. This involves developing reasoning and argumentation in order to give students instructional material. The method of creation will try to follow the activities which university lecturers currently employ.

6.1.1 Student-Computer Interaction

Many educationalists have examined the needs of students as they learn (see chapter 2). Most of all, at a tertiary level of education the teachers want their students to achieve a deep understanding of concepts. This requires the exercise and solidification of that new knowledge which has just been acquired. With any learning practice the student's approach to learning must be thought provoking. "Learning by doing" is a phrase often coined and doing involves experimenting, studying or solving problems. Accordingly the process of learning has been broken down into three stages:

- good preparation for learning,
- activity during learning,

- consolidation of understanding[34].

Psychological research has also proposed that for a student to engage successfully in this process they should be motivated. Truly motivated learning must originate intrinsically from within the student. Extrinsic motivators are necessary, though, to 'persuade' the student to be motivated intrinsically [7]. These motivators can be introduced by gaining the student's attention, ensuring that the material is relevant, making sure that the outcomes of learning can satisfy the student's need to succeed and hence necessarily build their confidence[53,55].

For the student to be motivated and satisfied during interaction with a computer it is important for them to feel in control[50]. A student in control of their learning will feel that their *own* efforts have led to satisfactory learning outcomes. This builds the student's confidence when they are aware of their progress relative to their colleagues and aware of what is expected by the institution. Activity in interaction will be beneficial and not simply an activity of pushing real or virtual buttons. Activity must be in response to thoughtful consideration rather than trial-and-error. Therefore control should be fulfilling, rewarding and require commitment.

Hence a teaching strategy is required that will give the student an opportunity to work at solving exercises whilst not taking the initiative away from them. Teaching strategies are difficult to author upon computer-based systems which have focused upon satisfying learning needs. These authoring needs will be explored later.

MacFarlane, in a poignant report, suggested that the phases to learning which must be fulfilled by teaching functions, are:

- orientating - setting the scene and explaining what is required;
- motivating - identifying relevance, evoking and sustaining interest;
- presenting - introducing new knowledge within a clear, supportive structure;
- clarifying - explaining with examples and providing remedial support;
- elaborating - introducing additional material to develop more detailed

knowledge;

• consolidating - providing opportunities to develop and test personal understanding;

• confirming - ensuring the adequacy of the knowledge and understanding reached. [54]

Furthermore, the dialogue which is formed as a result of the functions of teaching represents the interaction between the student and computer in CBE systems[19]. The computer system should provide the student with the resources to engage in this active dialogue. Generally this means testing their own hypotheses and obtaining appropriate feedback to satisfy or discredit their train of thought.

Computer-based Dialogues

For the teaching functions given above it is possible to suggest, in similar terms, forms of interaction in which a student might engage. Mayer's[20] (pp 162) description of how teaching techniques are used for designing expert computer tutors identifies three steps:

1. Observe the dialogue between real expert teachers and students and follow the strategies for good dialogue. These strategies are *systematic variation of cases, counter examples and hypothetical cases, entrapment strategies, hypothesis identification strategies and hypothesis evaluation strategies.*
2. Develop a database of topic information that can successfully utilise these teaching strategies. This background information is distinct from the learning methods and needs categorising so that a machine can work with it.
3. Formalise the instructional rules of 1. and the database of 2. into a computer program. This step assumes that artificial intelligence mechanisms are required but it is the dialogue and the background information that are the important aspects. The way in which they are put together need only satisfy the functions of teaching. Furthermore, authoring this final step for mechanical processing poses many difficulties when the rules are meant for an ITS.

Other non-ITS based computer systems are able to provide a dialogue that ensures a good learning environment. Expository learning strategies[20] (p 154) ensure learning by transfer of knowledge and requires the student to become actively involved with that information. They provide the pure sources of structured knowledge that can orientate, motivate and present new ideas to the student within a learning situation. The student can actively engage in a one-way dialogue with this resource material to gain an understanding of it. The student will ask questions concerning the concepts which they have heard about and try to find the answers from them. The passive material can also pose questions in the text. The reader must engage in activity to find solutions.

It is when material provides little new information and simply poses questions, that students must *discover* relationships by themselves. The student is asking questions but must spend more time and resources finding the answers. Even then they may not find the required answer, owing to a lack of guidance[20] (p 154). Guidance represents the dialogue which is missing in pure discovery. The danger with this kind of expository learning is that a student will be given too much information and not enough opportunity to use any new knowledge which must be transferred to long term memory.

Although LOGO [81] was not usable in reality for pure discovery learning it does provide a non-ITS dialogue. A student is told the basic functions and then is given the opportunity to use these functions in a programming context. The student gives the computer a description of how they feel the functions should be used. The LOGO interpreter answers the student with intrinsic feedback. That is, the functions either produce the desired effects or they do not work as expected. This confirms to the student whether or not they understood the functions. Mayer[20] (p 156) points out that the students using LOGO only discovered basic concepts and could not formulate and transfer those concepts to more complex programming problems. Nevertheless, the students were taking part in an instructive dialogue.

Coaching and on-line help systems[91] (for learning about a particular computer application usually) provide raw tuition about functions, actions, data and so on. They often give examples and allow you to follow these examples in the real system. In a similar style to LOGO they are allowing the user to express in the system their understanding of the functions. The computer responds by working or not working. On-line help provides the guiding feedback. So long as the student is able to pose any problem and get some kind of useful response they can learn from it. The result of interaction is often invisible in computer systems so in order to learn, the responses need to be made explicit. In LOGO, almost every function has an observable effect.

These methods do not generally provide for the early functions of teaching and assume a lot of prior knowledge. However these methods of clarifying and elaborating student conceptions are often simple but effective. In the later stages of consolidating and confirming, more is required in terms of practice and assisting the utilisation of prior knowledge. These phases are more difficult to satisfy than the preparatory stages and thus future systems aim to satisfy these confirmation stages.

Demonstration

In preparation for any assessment of their knowledge students require advice, coaching and demonstration in order to learn comprehensively, and in an efficient manner. The computer could give advice which will provide the "over-the-shoulder" guidance needed when a student applies facts and concepts to problems. The demonstration promises a familiar dialogue for learning and also a familiar environment for authoring. MacFarlane[100] pointed out, the important issue is to structure and manage the knowledge which a student will gain so that it can be applied.

The students learn most effectively from posing hypotheses and trying these out for themselves. Help systems and presentation systems try to pre-empt the students by providing raw data about the kind of hypothesis that the student might want to work through. Guessing possible hypotheses requires knowledge of the kind of questions that a student might ask. This guesswork is difficult and the resultant learning is shallow, because the guidance is passively directing the student. Later application of the knowledge may still require directing. To enforce a deeper learning style requires the student to actively engage in learning the material. Students need to direct themselves. This can be achieved by getting them to provide a solution which they feel is correct and then getting them to argue about it.

A strategy that exists to assist learning in real problem classes is to employ a demonstrator or coach. The demonstrator is there to help students as they tackle problems. The demonstrator gives clues and advice to students in order to help them work towards an answer. Only when a student has shown a deep understanding of the relevant facts and concepts will the correct answer be acknowledged. Students are required to verbalise their 'working' towards an answer. They are encouraged to argue their solution in order to prove to others, as well as to themselves, that it is correct. Deep learning comes as they assesses their own work with occasional help from others. The demonstrator provides that feedback as the students argue their solutions to problems.

It is the ability to ask for clues and generate partial answers which initiates a dialogue between the student and demonstrator. That demonstrator in turn guides students away from misunderstandings. Good human demonstrators do not attempt to work from prior knowledge but assesses each student at the time that he or she asks for help. Hence they are quiet participants in the learning process until the student seeks help. The tutors can spread their experience amongst the students effectively in the problem class. They are able to give individualised guidance to specific problems and provide the necessary feedback that is often required.

If a demonstrator is not available then the student may discuss problems privately with their colleagues. Peer tuition[7,8,20] has often been suggested as a method of improving the learning outcomes of students. It has many of the benefits of true demonstrator tuition but the students are working together to discover a plausible solution. They may take a great deal of time to do this because they may follow inefficient methods. When none of the participants know the answer, there is a danger that they will collectively lead themselves astray. However, the students will know the kinds of problems which they are all facing and have a similar base of knowledge. Hence their mental processes from prior understanding to ultimately new knowledge will take a similar path. This will make the retention and anticipated transfer of understanding more thorough.

6.1.2 Demonstrative Tuition

Much research in the field of computer-assisted learning has focused on the use of the computer as a surrogate teacher of facts and concepts. Only recent work has aimed at making CBE include practice at applying those facts to problems. In this way strategies for learning and teaching that give deeper understanding can be developed. One computer-based solution might reveal to students the kind of argumentative processes that an expert would use to reach a solution.

With demonstrative guidance it might be possible to force active interaction and thus ensure a deeper form of learning. In a traditional tertiary education setting, active thought occurs when the student is studying the material which they have been given to learn. During private study of text books or lectured material a student will often have questions which they want answered. Of course, questions may arise during a lecture presentation and students sometimes bring these up. But often they obtain answers by finding and asking a fellow student, a tutor or the original lecturer outside the lecture. However, the proper place (or medium) for this questioning is during a tutorial or a practical session when experimentation or discussion can be tried out. The vehicle for passing on problem solving skills is the demonstrator or coach. Hence it seems that the demonstrator's role within a laboratory session should be investigated for ensuring deep and active learning.

The Problem Class

For supporting learning, the problem class or tutorial provides the most benefit in the traditional learning environment. It provides a forum for students at all stages of learning and helps with many of the methods and strategies that students use[20]. The preparation of the problem class involves making sure that manageable groups are selected and that enough tutors are available to guarantee satisfaction of the needs of these groups[138]. This gives many students a place to work through their problems knowing that sufficient feedback will be available. The assistance and advice can come from their peers in addition to their tutors.

The groups are used to promote discussion so that a few people can help each other to learn. Usually each member of the group will have considered what they are going to say before saying it. Thus each participant in the group is actively thinking about their own comprehension of some knowledge so that they can make a valuable contribution to the group[137].

Before assistance can be given in a problem class, the student must identify a goal to be reached and formulate a plan of activities that if successfully completed will reach that goal[34]. Goals of course usually consist of sub-goals. In tertiary education formulating these goals and plans is the responsibility of the student. But the teacher can facilitate that activity by structuring lecture/reading material and by devising illustrative problems that grow increasingly more difficult to solve and more abstract in their presentation. Provided students perceive that they are leading their own learning despite the constraining structure imposed by the demonstrator then students will achieve a sense of gratification when goals are reached. What is important then is that the constraining structure is not demotivating in its restrictiveness.

Simply presenting problems to be solved (tutoring) is not sufficient. Even if students are given the opportunity for experimenting, reflecting and abstracting, there are two further factors that must be present in the learning environment. Students must want to learn, so they must be given motivators that encourage that desire, and they must be given feedback (coaching) so that they are able to gauge progress and ensure that they are not pursuing a learning path that departs from their goal[139]. The idea that students should be coached rather than tutored is not new[140,141]. Furthermore learning is more effective if there is sufficient assistance available to overcome impasses that prevent understanding[142].

Once a student has grasped the basic concepts of a topic they should practise applying those concepts. Text books attempt to provide the basis for this through exercise questions, but their stark answers often lack the insight needed for the solution to be properly understood. It is more important for the student to know why an answer is correct or for it to be clear that they understand effectively the aspect being examined, than for the student to reach the correct answer. Simply allowing students to browse through a model solution does not ensure learning but does offer some material support for deep learning. Of course forcing students to make a thoughtless decision (e.g. in a multi-choice system) in order to see the correct answer does not support the learning process though the student may be motivated to think before deciding. By putting such a temptation in front of students may not cause them to be aware that their learning is shallow and of course their approach would be rebuked by a human teacher. For the serious student who is unable to understand the flaw in a misconception, or does not know how to begin to solve a problem these tutoring systems are of little help.

Students are intelligent and creative entities[116]. With lateral thought they can prise out the solution to a problem given sufficient time; and in the past they have been able to learn material without any computer aids. But there is a time limit beyond which it is not cost effective to continue to try and solve a problem. Automated over-the-shoulder guidance techniques are motivated by the desire to ensure that this time limit is never reached and thus they are an attempt at improving student learning efficiency. The important thing is to provide the cues so that this lateral thinking can be facilitated.

Automated Problem Class

Many problems faced by students do not appear at first sight to be straightforward, indeed they may not be, but the perceived difficulty can be a deterring influence on students. Making a student want to answer a question that they currently feel they cannot complete is a challenge for the teacher. While the problem class or laboratory session provides the forum for practising, an individual student in a large class cannot always engage the demonstrator (or coach) at the right time or have the lecturer present just as conceptual mistakes are being made.

What is necessary is for the student to have face-to-face contact with the lecturer or a locum at any time during the learning process. In this way their growing reluctance to pursue a difficult problem would be thwarted by a progressive revelation of argument and by relevant feedback to their attempts at a solution: together these build confidence that encourages continued learning. Thus a process of providing informative and relevant course material, that will confidently be answered to give satisfaction is required. Relevance, confidence and satisfaction are derived within Keller and Suzuki's ARCS model of motivation in instructional design[55] but they apply equally to the activities of the demonstrator. In essence, the role of the demonstrator during student problem solving is to facilitate the identification of specific knowledge and guide the student's thoughts as that knowledge is applied to the problem. A demonstrator provides many of the motivational cues that a learner requires. A good demonstrator will not simply reveal the answer to students before they have made an attempt.

Having an automated demonstrator allows for students to work at their own pace and be able to study privately. The demonstrator promotes the student's ability to argue through a solution to a problem. They do not merely present the answer, but encourage the student to consider all the aspects and as well as providing clues.

The foregoing suggests an ideal support for the process of learning to solve problems, but it is clearly not feasible to provide, on a one-to-one basis, human demonstrators to fulfill this role. A computer solution is the desired alternative, and at first glance it suggests that an intelligent tutoring system (ITS) needs to be employed. A number of experiential considerations make this approach unsafe.

> First, the teacher is generally not an expert at programming production rule-sets. Thus either special personnel would need to be employed to do the task or the teacher would spend many months gaining familiarity with the technique.

Second, the rule-sets are generally applicable to a narrow area, and so for each problem a new set has to be generated.

Third, the explanation derived from the rules and given to the student has to be conveyed in their own lucid language. Converting rules of artificial intelligence to English is not a trivial task.

Fourth, the ability to model students should take account of the fact that what is remembered one day is forgotten the next, but recalled the following day and that reminding the student about what they already know can actually improve confidence. Conversely confidence can be destroyed by a system that incorrectly assumes a student's ability.

Finally, students are intelligent in their own right; what is required are the cues and inspiration that trigger their cognitive processing in the direction that enables them to confront and then solve a problem.

It is possible to impose a dialogue on the student without the use of artificial intelligence techniques[19]. Even so, an environment which is akin to the problem-class situation is still required. It is the resources which enable students to test hypotheses and then receive instructive feedback which must be made available. This will enable a student to prove or disprove their own reasoning (p 392)[20]. A mechanism which is proposed to provide this resource is argumentation. The student will have to argue through their solutions as in a problem class yet instead of having a real demonstrator encouraging this, the student has an automated system.

6.1.3 Argumentative Instruction Design

In essence then, the design of instruction must encourage students to want to learn and thus early questions must not appear to be insurmountable. The problems that are provided by the lecturer must be graded in their difficulty and collectively they must cover a topic completely. As the understanding of the topic becomes more apparent to the student, they must be able to move on to a new topic, whilst a less confident student continues to answer further questions that remove the last vestiges of misunderstanding. It is important that once the student's enthusiasm has been captured, it is maintained. This can be achieved with positive feedback that is based upon student activities and not forced upon them; thus, a student gets relevant advice on progress as and when that student emotionally and intellectually requires such support. The motivating factors are largely determined by the lecturer. Over-the-shoulder guidance merely provides the framework within which the factors are available.

Because problem solving involves questions and answers, a common option for automation is to make use of a multiple-choice mechanism. Multiple-choice can quickly discover if a student knows the correct answers to questions and it lends itself well to computer implementation. However, multiple-choice is intended to assess, rather than assist, learning. Students definitely require assistance when doing multiple-choice, and learning will be heightened by this assistance. Two problems exist with multiple-choice: i) it is difficult for authors to devise feasible but incorrect answers (distractors) for a multi-choice test, ii) in multiple-choice CBE systems it is often possible for the student to cheat (themselves) by randomly selecting answers and using trial-and-error to get the right solution. Thus it can be seen that assessment must be used in order to force students to attempt a correct answer first time. Otherwise comprehensive understanding will only come after many wrong answers.

A CBE system that assists in the problem class should not require an answer to be authored for every conceivable request for help. Instead, only the method of how to achieve the correct solution is needed and this should provide the argumentation from which the student can learn. The assistance can now be based on a known train of thought (the arguments) rather than guessing what might be in the mind of the student. If this is the case then the system can merely provide the authored information when the student needs it. No artificial intelligence is required, only methods for selecting the best assistance in order to get to the right answer. Thus the lecturer needs only to author a question, an answer and the way in which the answer can be reached. This is an activity that most lecturers must do already when setting examination papers.

Argumentative Process

When lecturers design problems that are to be solved by students they are using the problem to identify whether the student knows the underlying facts and understands the underlying concepts. In other words there is a rationale behind the problem and an argumentative process that supports its solution (Figure 6.1). This, combined with the steps of the process usually constitute the full model answer to be found in a recommended text book. It is up to the student to integrate the solution with their factual and conceptual cognitive network[10] that has been derived from lectures. The existing cognitive network may, of course, change as a result of understanding the whole problem and answer.

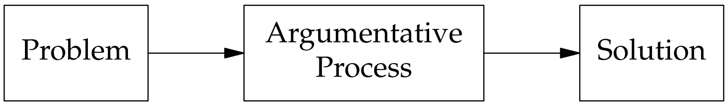


Figure 6.1: Problem solving incorporates argumentation

Simply put, an argument is "a connected series of statements intended to establish a proposition."[143] A more formal investigation of arguments was presented by Toulmin[144] in 1958 which adds details to the kind of statements that might be used. Toulmin divided an argument into its informative parts called **data, warrants, backing, claims, qualifiers** and **rebuttals.** The data (D) is the initial state of factual material which leads to a claim (C) but this claim may be made in the presence of qualifiers (Q). The claim may have a number of conditions for exception which are known as the rebuttals (R). The data itself may require evidence which are represented by the warrants (W) which in turn can have backing (B). Figure 6.2 shows a diagram of how these interconnect according to Toulmin (p 104).

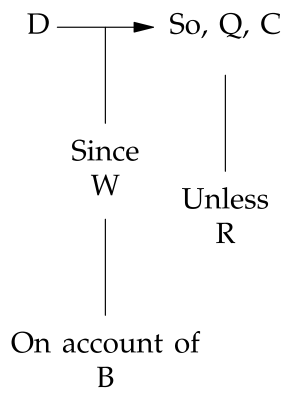


Figure 6.2: The layout of arguments (from Toulmin)

Recent research has focused upon how to develop a good argument and how to evaluate arguments[145,146]. The kind of argument model which they present are based upon two elements. **Reasons** and **premises** are the basic elements which then lead to **conclusions.** Fisher[145] then goes on to describe a variety of classes for reasons and premises and how these can be joined logically into forming a conclusion.

Computer-based applications of arguments and reasoning have focused on the composition of reasoning components for rationalising the design process. Lee and Lei[147] give a number of different conjunctions which might be made for these compositions such as **supports, denies, presupposes, logically implies, qualifies, specialises, generalises, elaborates** and **simplifies.** These are all useful in developing and designing an argument and they can be used without computer support. It is advantageous though to use computer support for evaluating and proving the correctness of such arguments and thus the designs. Systems for supporting the design of argumentation can become rather complex and hence a great deal of research into supporting Design Rationale now exists[148]. However, the use of argumentation to assist with understanding the rationale for designs has also uncovered some problems[122].

To maintain a simple authoring mechanism for lecturers in a computer-based instructional design system the arguments are not broken into the specific components as defined by Toulmin. In contrast, justification fragments can be said to exist in 3 forms: i) to initiate an argument, ii) to maintain the argument, or iii) to form a conclusion to the argument. Hence, they form 'start', 'middle' and 'end' justifications (Figure 6.3).

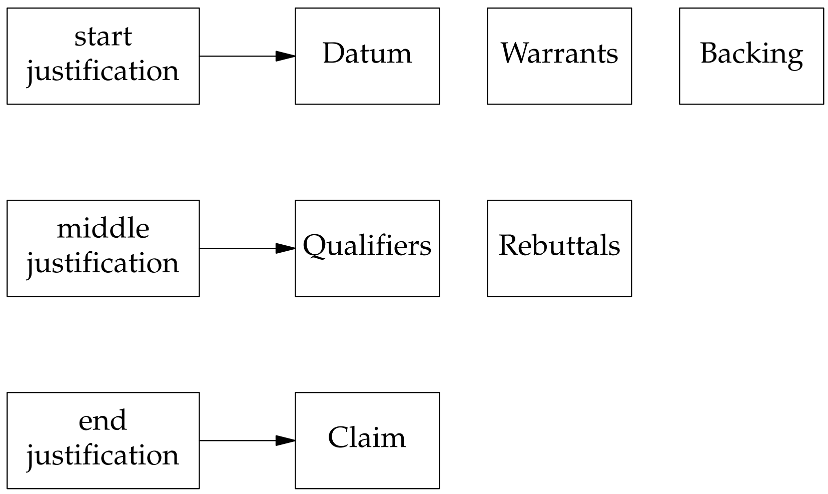


Figure 6.3: Justification of arguments

The datum, warrants and backing relate to prerequisite knowledge which a student should have along with any information presented in the question. The author will then need to make qualifications and rebuttals which will help to define the final answer to the question. Final justification of the solution will be formed from one or more claims. Overall, justification fragments will consist of all of these factors to some degree. Condensing Toulmin's components will give an untrained argument builder easier access to the concept.

Clues

Once the argument is known, the student must be able to identify this same argument. From a given exercise question to its answer there may be more than one train of thought. However, the teacher has only generated once such path. Some mechanism is required to focus a student naturally to the authored argument. A familiar technique which is employed by demonstrators is to give clues and hints (Figure 6.4). The student can develop an idea of the lecturer's thoughts through the clues given. They provide essential vocabulary so that the student can successfully design a solution plan.

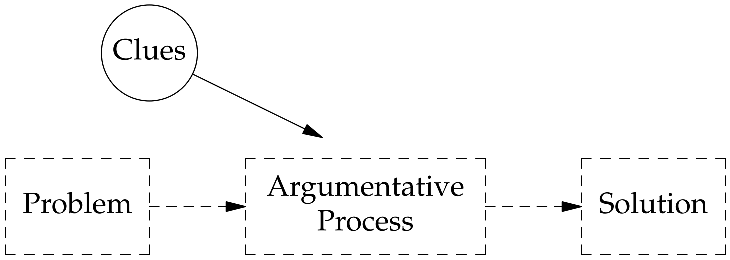


Figure 6.4: The role of clues in problem solving

The clues and hints need to be devised and authored in advance. This extra work for the lecturer is minimal since a good question should be designed to exercise the student's underlying knowledge of concepts by allowing them to apply their knowledge to the question. Hence much of the lecturer's own reasoning behind the question provides the clues and hints that should be incorporated. Remember, these questions are not designed for assessment, but rather are designed to consolidate understanding.

The clues are associated with justifications and they are meant to help the student build an argument; so the justification ordering must be preserved. Clues can come in two forms: i) those which relate to justifications and aid the student towards them (start, middle and end clues), ii) those which relate to the question as a whole and aid the student generally towards any one of the fragments. It is the arguments and clues that have to be authored for automated over-the-shoulder guidance to be successful.

6.1.4 An Example of a Justified Problem

When a physics lecturer uses this system to assist their tuition of the mechanical properties of materials, they may develop a question in a text book such as the following, after Duncan[149].

Two wires X and Y are made from the same elastic material. X has twice the diameter and three times the length of Y. When the two materials have the same tension what is the ratio of their energies?

Question 1.

The lecturer will already know the answer to this question and will probably author it as:

The ratio of the energy contained in the wires X and Y is 3:4.

Answer 1.

It is from the following facts and the original question that a lecturer will expect a student to be able to understand that the energy contained in the wire X will be $\frac{3}{4}$ of the energy in Y.

- The materials are the same, so $E = \frac{F_X}{A_X}\frac{l_X}{x_X} = \frac{F_Y}{A_Y}\frac{l_Y}{x_Y}$.
- Both wires are stretched by the same tension, hence $F_X = F_Y$.
- The cross-sectional area of X is 4 times that of Y, and the length of X is 3 times that of Y (i.e. $A_X = 4A_Y$ and $l_X = 3l_Y$).
- The ratio of the energy in X to the energy in Y is $\frac{F_X x_X}{F_Y x_Y}$.

The aim of the question is to express that all elastic materials have a property which can be expressed with the *Young Modulus.* The Young modulus, E, is the ratio of stress to strain that a material can take. Because of this, the energy stored in a material under tension is the same for all materials with the same modulus. The lecturer may also want to ensure that the student notes that Hooke's law is important because of its relationship to the Young modulus even though it does not enter the equations. That is, the energy stored in the body is only proportional while the yield point of extension is not reached.

So now that the lecturer has developed a train of thought, they can aim towards defining the justification and clue fragments. A general clue fragment could be the following:

Consider Hooke's law [†] and the Young modulus [‡] relating to the ductility of materials.

Clue 1.

In clue 1, † and ‡ could be references taking the student on to material that they should have already covered.

Now the justification fragments will be authored according to the facts presented earlier. These are paraphrases of the information the lecturer has but given in a way which presents supportive evidence for any claim which the lecture is making. The lecturer knows that an understanding of the "energy" in a sample is required to get to the answer. This is a claim made by the solution.

> When a body is under tension and does not exceed its elastic limit, the strain energy contained within it will be equal to the work done in extending the sample:
>
> $$energy = work\ done = Fx$$
>
> where F = force applied and x = extension.

End Fragment (Claim).

Before this, the student will have to reason about the properties of similar materials to be able to discover how they compare when their dimensions are different. This fragment will back the existence of this relationship.

The Young modulus provides a relationship between the amount of stress and strain that occurs in a material under tension.

$E = \dfrac{stress}{strain}$ where $stress = \dfrac{force}{cross\text{-}sectional\ area} = \dfrac{F}{A}$ and $strain = \dfrac{extension}{original\ length} = \dfrac{x}{l}$.

Start Fragment (Datum/Warrants/Backing).

The argument must be supported with a description of the relationship between forces and extensions.

Hooke's law states that the extension of a body is proportional to the force applied to it. i.e. $F = kx$ where F = force, x = extension and k is a constant.

Middle Fragment 1 (Qualifiers/Rebuttals).

Furthermore a qualifier for the claim may be given in a second middle fragment.

Hooke's law only applies when a body has not reached its *yield point* or *elastic limit*.

Middle Fragment 2 (Qualifiers/Rebuttals).

Thus all of these fragments will confirm to a student the considerations being made to solve the initial problem. They do not necessarily give the answer, but once a student has found these fragments they should understand the relationship.

6.2 A System to Support Deeper Learning

This research was undertaken within a computer-assisted teaching and learning environment that is firmly rooted in the traditional methods adopted in the tertiary education sector. It was developed within the Automated Office Metaphor [150]. All factual and conceptual knowledge is conveyed through On-Line Lectures that provide a framework for the course, a boundary for each topic, and ideally an encouragement to pursue further study. A more detailed description of the mechanisms employed by the On-Line Lecture concept can be found in[1] or in chapter 5. The interfaces are built upon the book metaphor provided by the Book Emulator [5]. This has a look-and-feel similar to that of a real book, with page turn animation and positional information cued using splayed page images. Users can flick through material in much the same way as with a real book.

A new element in this learning environment is the 'Hague Educational Argument Research Tool' or HEART that consists of two parts which are connected via a compilation unit. 1) The authoring tool for specifying the arguments is known as the 'text book'. 2) The learning tool or courseware consists of an 'exercise book', a 'justification book' and a 'clue book' (figure 6.5).

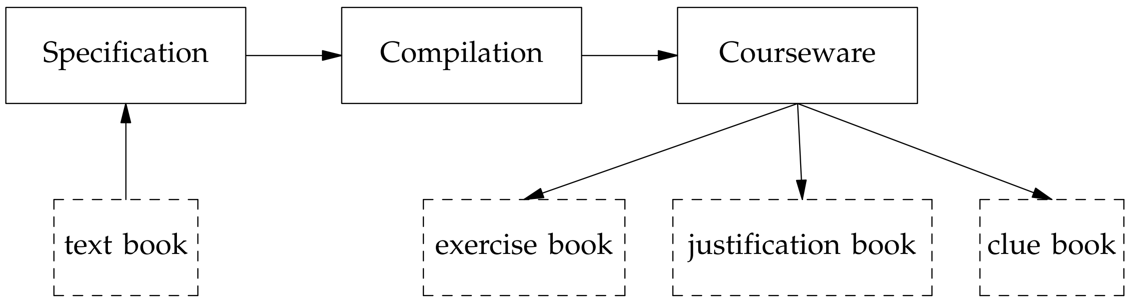


Figure 6.5: Process of course creation

6.2.1 Authoring Over-The-Shoulder Guidance

The author interacts with the system via a text book. This contains the textual and graphical information that the teacher wishes to present to the student. It is manifest in a linear and browseable fashion that is simple for the author to follow.

For the teacher to focus on the problems of teaching a course the authoring should not require additional understanding of how to interact with the computer. The system proposed here should enable the visual content of educational material to be presented usefully to students without the need for conventional programming. Thus the teacher must be able to organise the material into argument components so that the system can compile this information into the courseware which the student accesses.

Content Authoring

```
$ new_heart Physics1 # Create a new text book called 'Physics1'
$ edit_heart Physics1 # edit the specification
                       in the text book 'Physics1'
```

The interface for authoring allows lecturers to **mark** a text book with the following components: questions, arguments, clues, and the answer. A similar schematic method is also implemented for marking on-line lectures[1] for presentations. Each of these components can consist of text and graphics; the clues can contain audio material, and hyperlinks (which provide access to reference material).

Authoring the material for an exercise is done on two pages in the text book. This is shown in Figure 6.6. The margins are clearly visible and it is within a margin that the author places **marking symbols**.

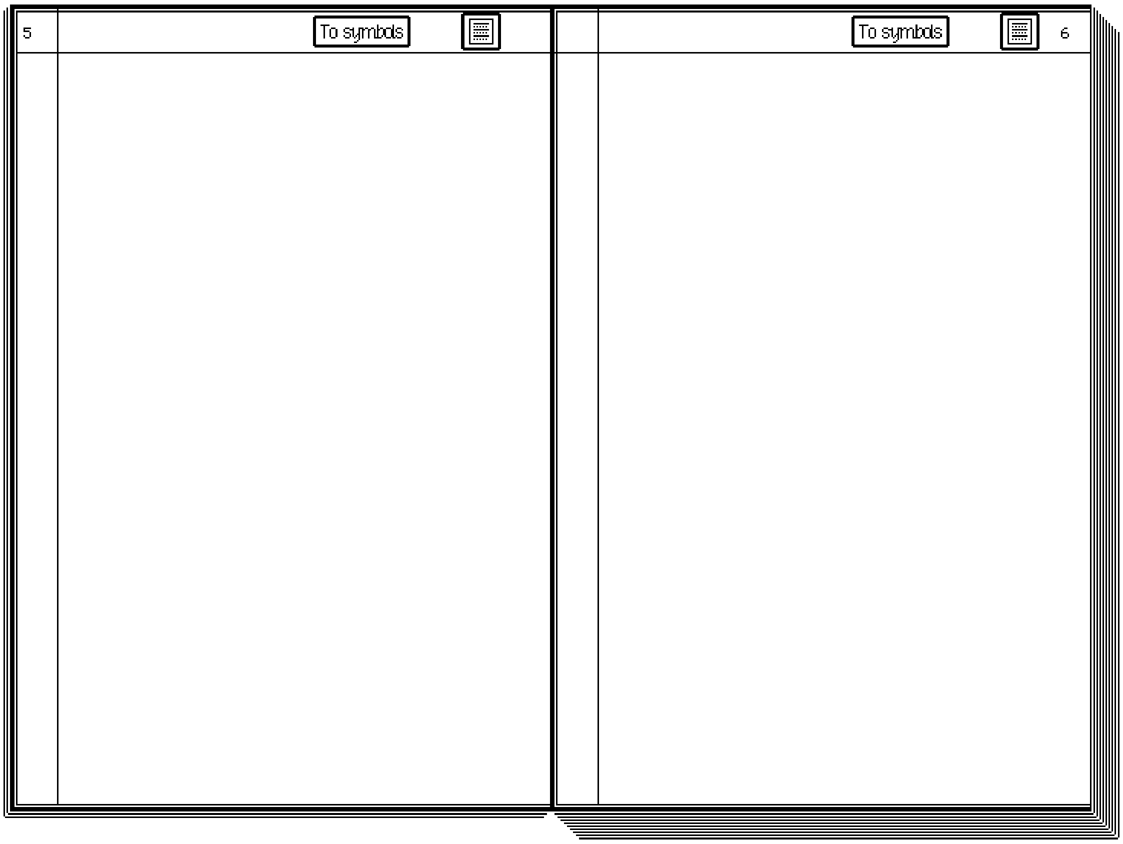


Figure 6.6: A text book with margins on the left of each page

Text and graphics can be used to author the content of questions, answers, justifications and clues. Figure 6.7 shows examples of pages marked up with text and graphics.

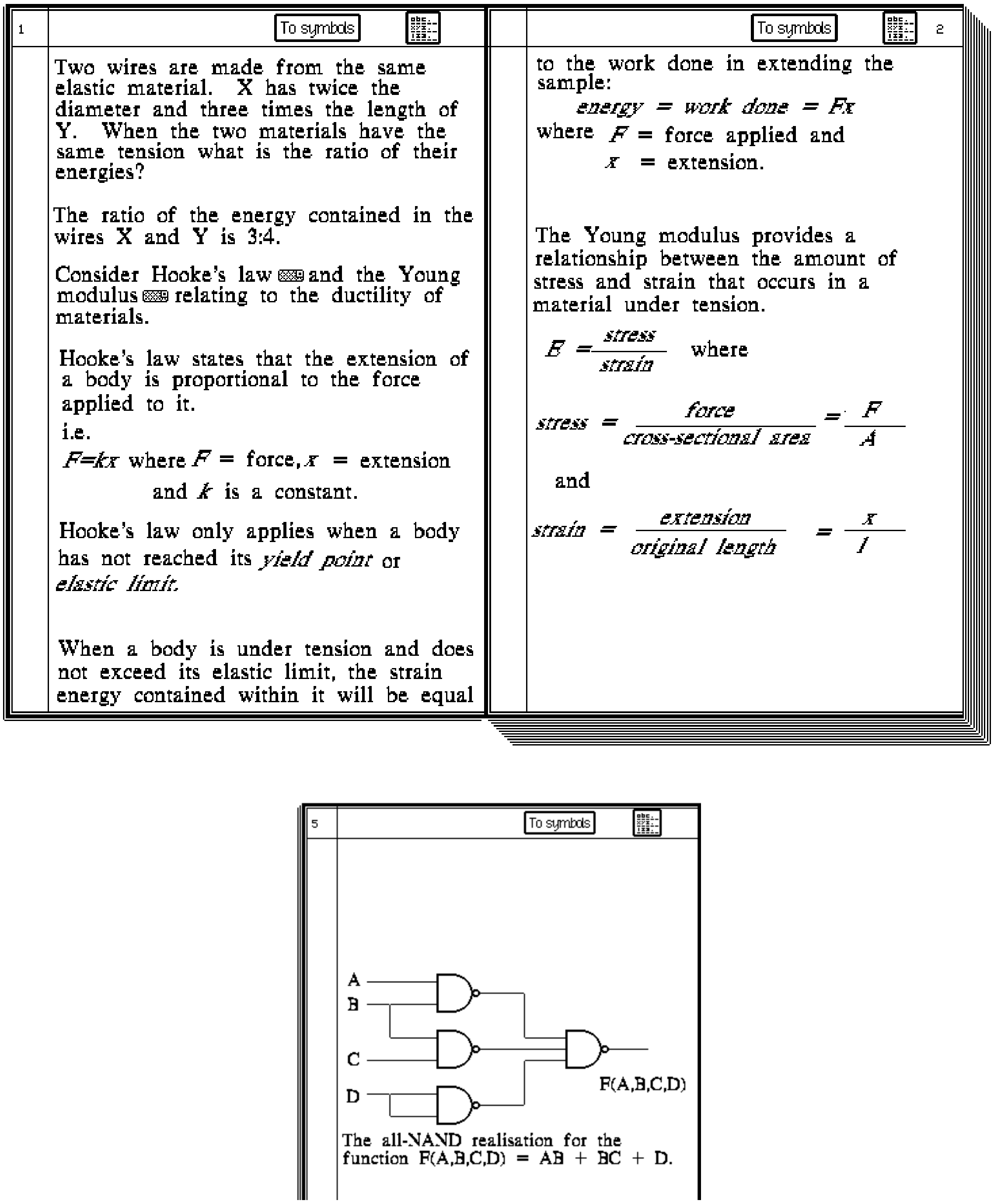


Figure 6.7: Actual text and graphics authoring

Reference authoring

In addition to simple text, it is also possible to author references to other books in the system. This enables additional material to be referred to directly from the exercises. Generally this is used in the clues to assist a student who is having difficulties. Notice the two references in the clue are authored using a 'hyperlink' mechanism that exists in the Book Emulator. Long-clicking on the reference symbol will open the books to which they refer.

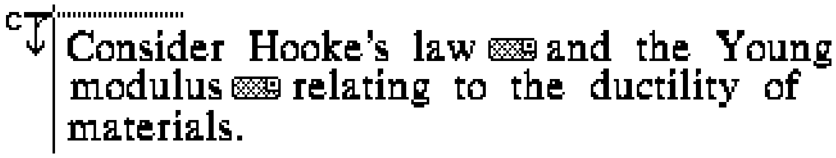


Figure 6.8: Reference authoring

Speech authoring

It is possible to annotate text and graphics with audio samples. These audio samples usually contain speech. Hence some material can be transient and not require visual reference. Clues are most useful with speech. If a clue is spoken then the clue book need not be materialised. Now the student's focus of attention can be maintained on the question and justifications.

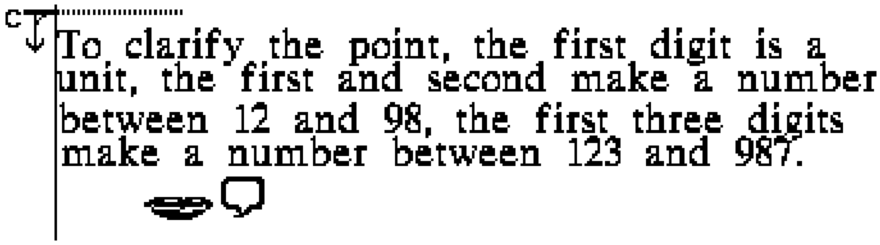


Figure 6.9: Speech authoring

A long click on the mouth symbol will play the sound sample associated with it (Figure 6.9). After picking up the symbol, using the F1 and F2 function keys will change the symbol to reveal a textual representation of the spoken text. Information about when the sample was created can also be found.

Speech authoring for narratives and so on is the only part that has not been adequately constructed. A speech capture book was intended to produce the schematic symbols that mark a spoken narrative. The system can already recognise where speech has been authored but at present the symbols and samples are generated by hand. All that is required is a method of recording the samples and then linking them to the mouth symbols automatically. A prototype mechanism was developed.

Margin Markup

The **marking symbols** which are placed in the margins allow the author to separate the various text and graphical items. This is done in a linear fashion so that a lecturer will immediately see how the material is structured.

The author knows where each question starts and ends, and where its answer starts and ends. Hence, the author can easily place the marking symbols for the authored text (figure 6.10).

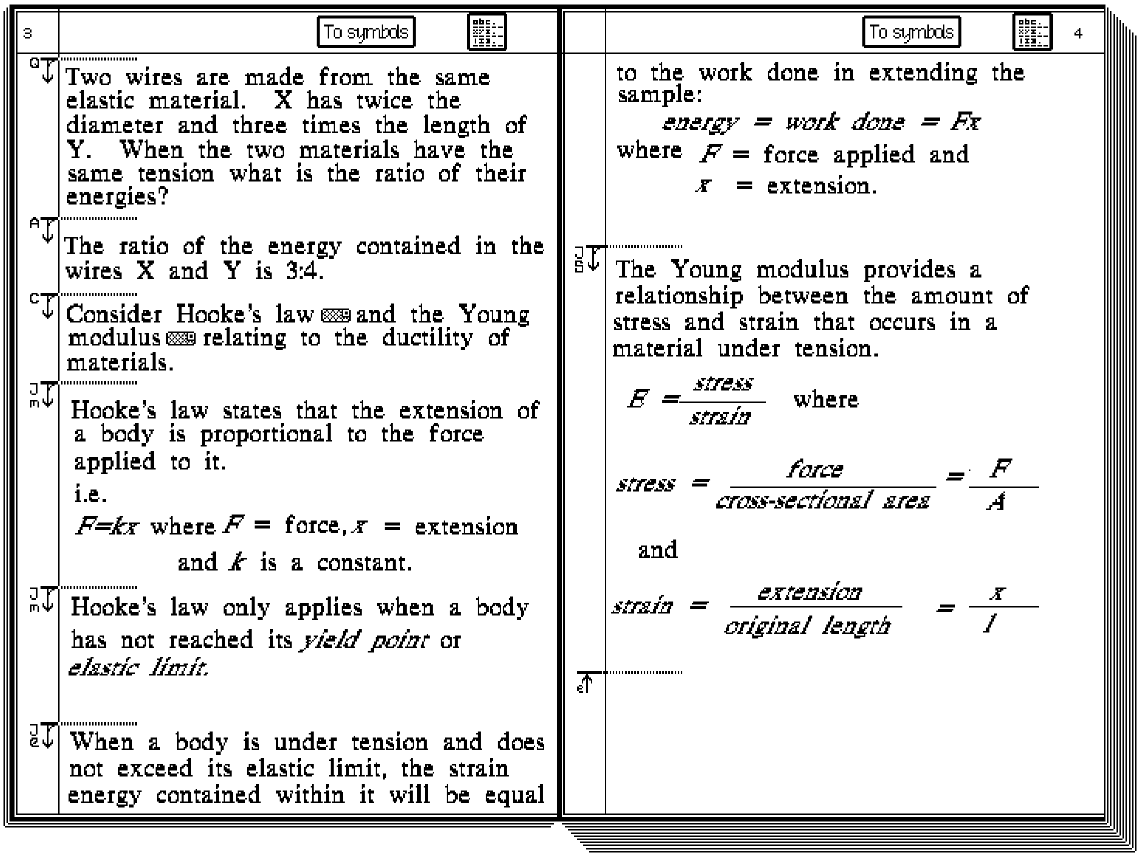


Figure 6.10: Marked exercise (see figure 6.7)

The start of a new section automatically ends the previous one because no two pieces of information should be mixed. All the other **marking symbols** (Figure 6.11) work similarly.

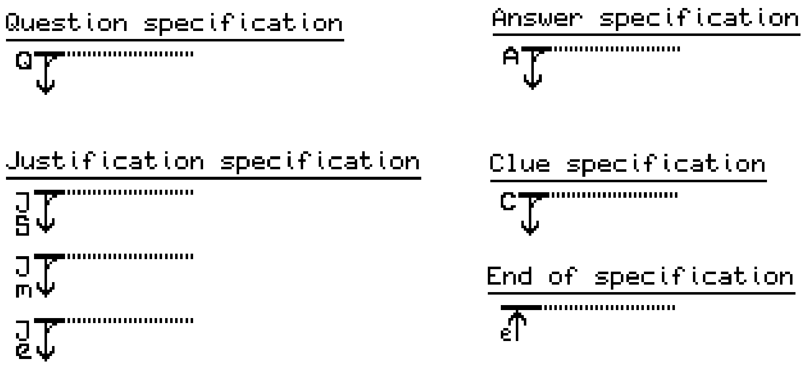


Figure 6.11: Marking symbols

Clues can follow a question or a justification. Depending upon their placement, they are associated with the most recent of these components. That is, a clue to any justification fragment or a clue to a specific justification respectively.

6.2.2 Generating Over-The-Shoulder Guidance

```
$ create_heart Physics1 # compile the courseware
                          specified in text book 'Physics1'
```

The process of creating three course books from one text book requires the information to be reorganised usefully. The questions and answers are easily placed onto double pages for the student. However the justification fragments will have to be randomly distributed throughout the 'justification book'. The clues similarly must be organised so that they can be retrieved in a suitable order when the student requests one. All the links between books must be established so that, for example, a clue request for question one will retrieve only clues associated with question one. When a clue is requested, clues for justifications that have already been placed must not be given.

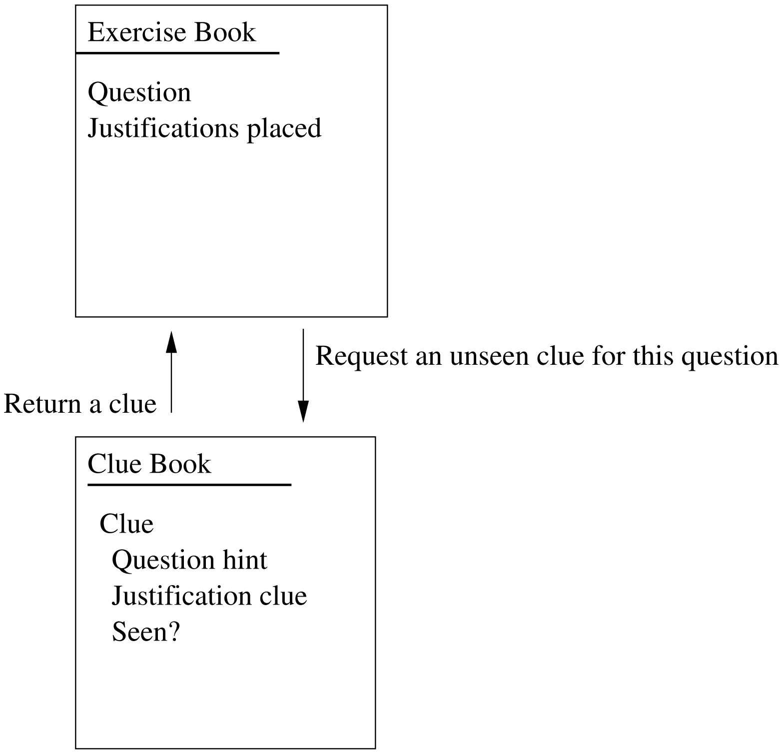


Figure 6.12: Internal courseware linkages

```
$ open_heart Physics1 # make the courseware open to students
```

Core material is made available to students globally but any annotations and answers which they make will be local to their books. To control this, the teacher will provide access to a course of exercises only when authoring is complete. Any updates to the course made by the author will need to be made available separately. A mechanism for properly versioning these courses could be installed. The access rate of course books as statistical data could be given to lecturers in a future system if required. This might assist them in refining difficult parts of the course.

6.2.3 Learning with Over-The-Shoulder Guidance

```
$ heart Physics1 # use the courseware called 'Physics1'
```

HEART incorporates the over-the-shoulder guidance techniques by again utilising the Book Emulator[5,151] as its interactive metaphor. The implementation of this argumentative style of learning required a simple interactive metaphor so that students will be familiar with the interaction required. To retain a relationship with current methods of instruction the main metaphor is an exercise book (question and answer book) which contains a set of exercises. This book is interactive and it can accept an argumentative dialogue from the student that will ultimately reveal the answer to the student.

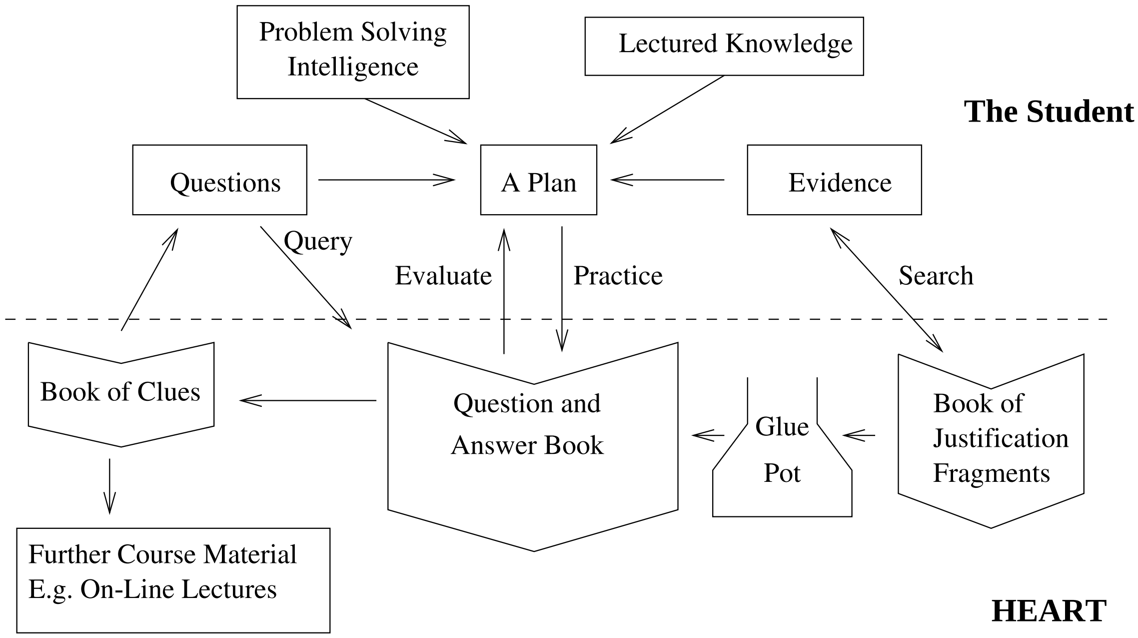


Figure 6.13: System architecture

The BEM glue pot is used to copy and paste justifications from the justification book to the exercise book.

Questioning

Each question is presented on a new double page spread of the exercise book with space available for students to plan their answers (Figure 6.14). The solution to a question is planned through justification and the result of this is placed in the space provided. The result will be the justification fragments as authored by the teacher. After the planning is completed the student will press the answer button and the answer will be shown but only if the correct justifications have been placed. The student is able to carry out the following planning activities: a) search for a justification fragment contained with many other fragments in the 'justification' book, and b) ask for clues that will help to lead to the identification of the next argument in the problem's solution. The clue will be 'spoken' if a sound sample has been authored, otherwise the clue book will materialise to the front of the display and show the relevant clue highlighted. Clues are associated with both the problem and the argumentative process.

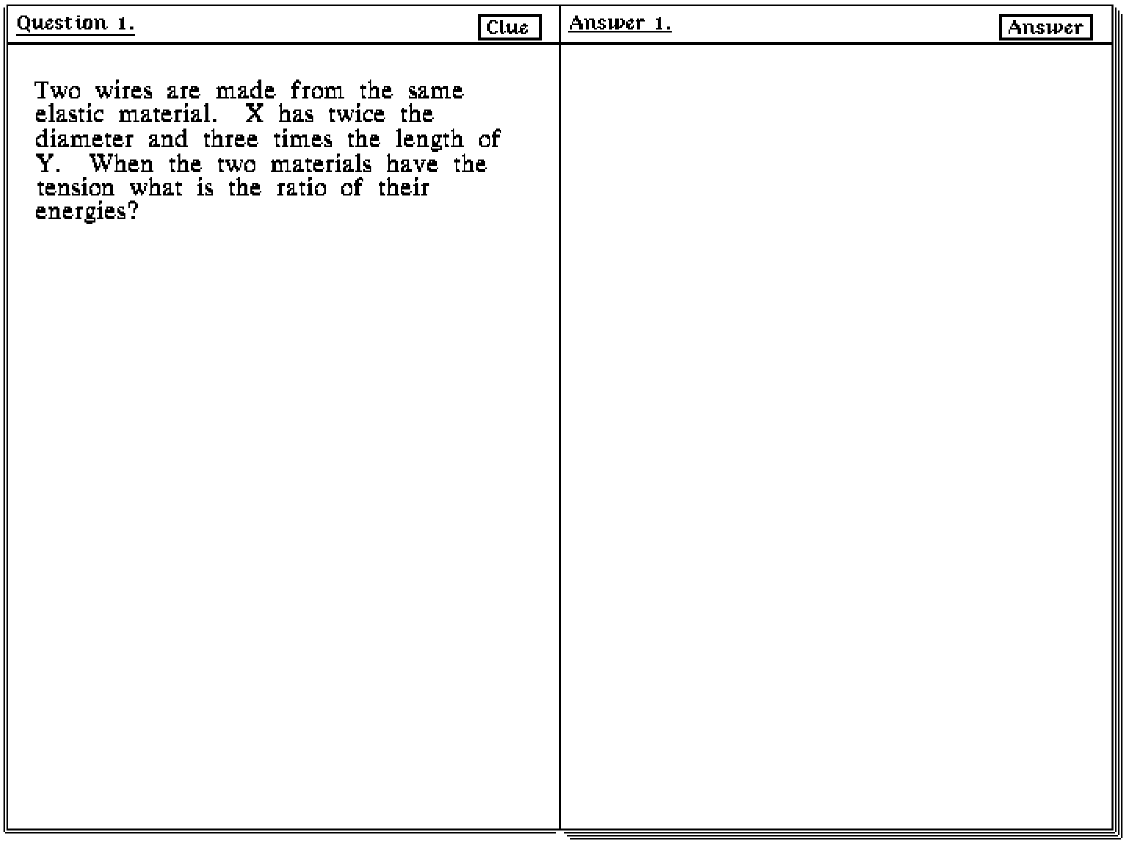


Figure 6.14: Exercise book

Planning

Even before planning the student may have a solution and merely wish to check their answer. However, it is necessary for the student to show their working. The student requires a mechanism for expressing their argumentative dialogue to the system. Free-text entry is not acceptable because of the necessary processing complexity and because the student may not have the necessary vocabulary to express their arguments. Rather than rely on the student to argue in their own words they are forced to argue using fragments of reasoning that were authored previously by the teacher. These fragments contain conceptually sound arguments but ideally have no direct relationship to any particular question. The student would read a number of arguments in order to select one which they feel justifies their own answer. Some of these may be deliberately false (distractors); but most would be a correct justification for at least one question in the book. In other words students read the questions, devise their own answers, and reason (using the fragments available) why they think their answer is correct. This encourages students to think more deeply about their answers.

If many fragments exist then the student may have trouble finding the justification they want simply by flicking through the book. To solve this problem there is a simple text search scheme implemented that allows the student to search interactively for justification fragments. Once the search is complete, links to all the fragments that match are listed below the query.

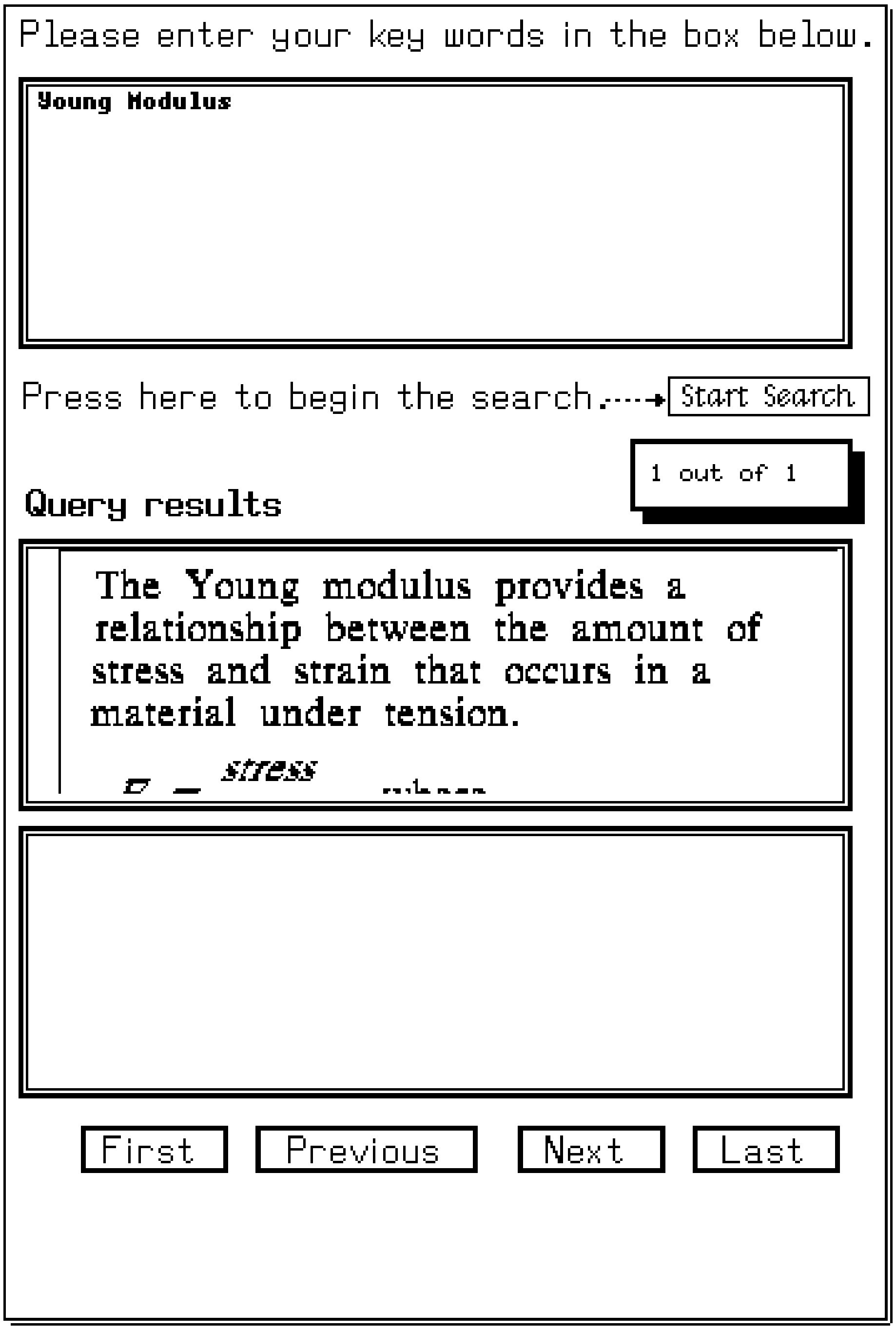


Figure 6.15: Justification search mechanism

For example if the student searched for the phrase "Hooke's law" they would find the fragment shown in Figure 6.16.

Hooke's law states that the extension of a body is proportional to the force applied to it.
i.e.
F=kx where F = force, x = extension
and k is a constant.

Figure 6 . 16: Fragment of justification

Assistance via clues

For the learning point of view, what if the student is in difficulty? It is demotivating if the next step in the solution is beyond the student's comprehension. Computer learning aids are supposed to help the student and must do so even if they provide support for the lazy student. Weaker students will not understand how to get an answer from the question. It is at this point that the student requires assistance. In a problem class the student will ask a demonstrator or teacher to help them find an answer. In the library they might use reference material and clues given in the recommended text books.

As already described, HEART should not immediately give an argument that leads to the question's solution. Instead it can give ideas which the student might use to plan a solution, or show how the question relates to material previously covered. To spark some insight, the student can request a clue relating to the argumentative process being searched. The authored clues are available on demand to help the student search for the justification.

The clues are related to the justification fragments in the system or they are related to the question as a whole. Thus requesting clues can initially provide the student with information relating to justification fragments which they have not already placed in the exercise book. Clues are not repeated once they have been seen during a session. If all the clues relating to a particular unfound justification have been displayed then the more general hint about the entire question is given, provided one has been authored. Note that the answer will never be shown until the correct justifications have been found.

Clues can also include reference to further material such as on-line lectures, text books and other good traditional learning material. So when students are still in difficulty after having viewed original course material, lectures, tutorials and text books, and none of the clues help, then either they cannot work with the system or they have severe trouble with the problem space. In both cases they are encouraged to seek human assistance. The percentage of students in this category is likely to be very low and so a major burden on teachers will have been lifted by this system.

On the page with the question, the button which students press to receive a clue is clearly visible. If a spoken narrative exists for a clue, it is played when the button is pressed. If no audio is available the 'clue' book (Figure 6.17) materialises on the screen with one of the authored clues clearly highlighted on a page. At this point the student can either close the 'clue' book or click on a hotspot (the '?' symbol) to go to other books containing material related to this clue and ultimately to the question.

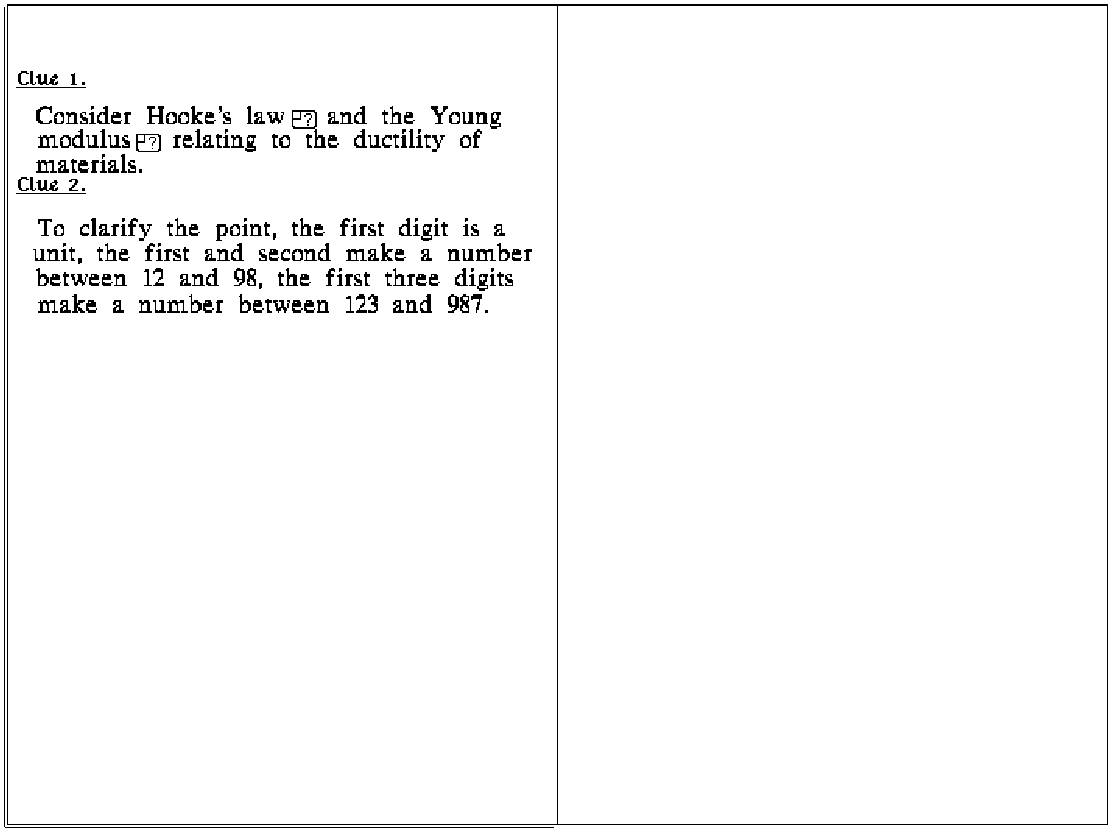


Figure 6.17: Clue book

Although clues come in two forms (those that are associated with justification fragments, and those that apply generally to the question) this distinction is not evident to the student.

Answering

Enabling an interactive CBE system to interpret the correctness of a student's answer can be difficult. When a student selects an answer from a given number of options the CBE system can determine that the choice was correct very easily. Whereas, free-form typing of the answer is the most difficult for the computer to judge because it requires advanced pattern matching or feature extraction from both the student's answer and the correct answer[152]. By requiring the student to search in a book of justification fragments and using a drag-and-drop mechanism, the internal technical benefits of multiple choice interpretation are gained and the student is unlikely to guess the right justification for the wrong reasons. These fragments are verbal and therefore can either be searched visually by flicking through the book or searched textually using a conventional keyword search as described previously. When the justification fragment is placed in the 'exercise' book it is a simple matter to match it with the one required. If it is correct then the answer to that stage of the problem is presented to the student. In practice, more than one justification may be needed before the correct answer feedback is displayed. This will reduce the student's willingness to just guess when selecting fragments. Obtaining the answer to a carefully thought out argumentative process is the positive feedback needed to gratify the student. The focus is on the underlying reasons behind the answer and not on the answer itself.

When students choose a fragment, they place it on the same page as the question. This enables the system to decide locally on the correctness of the student's answer and it also enables the student to refer to the argument at a later date. Since books remain static between invocations, the student can return to incompleted work in order for it to be finished, or return to completed work for revision.

For students to discover if their argument is correct they must first place all their chosen justification boxes into the exercise book. Visible in the exercise book is the answer button which students must press to reveal the answer when their argument is correct. If too few correct justifications or too many wrong justifications have been placed there then the system will indicate this with coloured pegs. White pegs are incorrect fragments and black pegs are correct fragments. The holes which the pegs fit into represent the number of fragments that are to be found. The order of the pegs does not represent the placement order of correct and incorrect fragments. (It is similar to the puzzle game "Mastermind".)

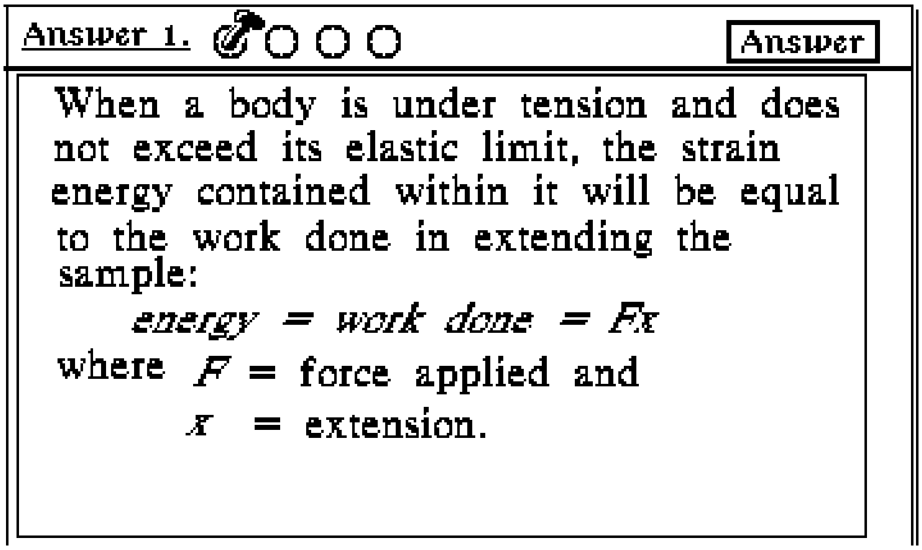


Figure 6.18: One correct justification fragment has been placed out of four

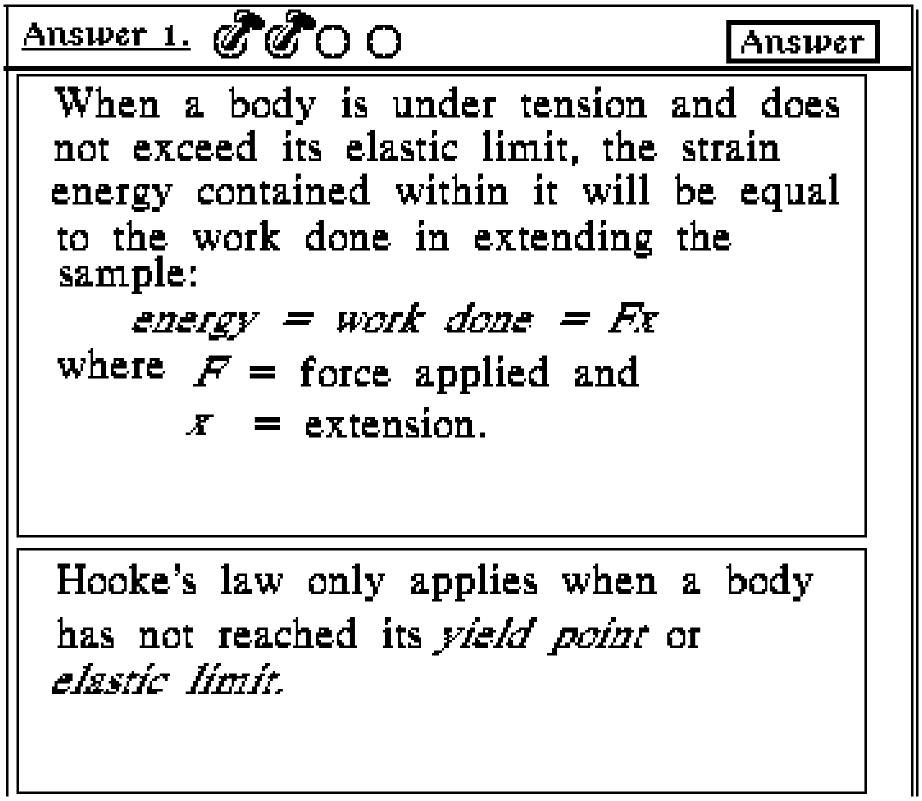


Figure 6.19: Another correct fragment has been placed

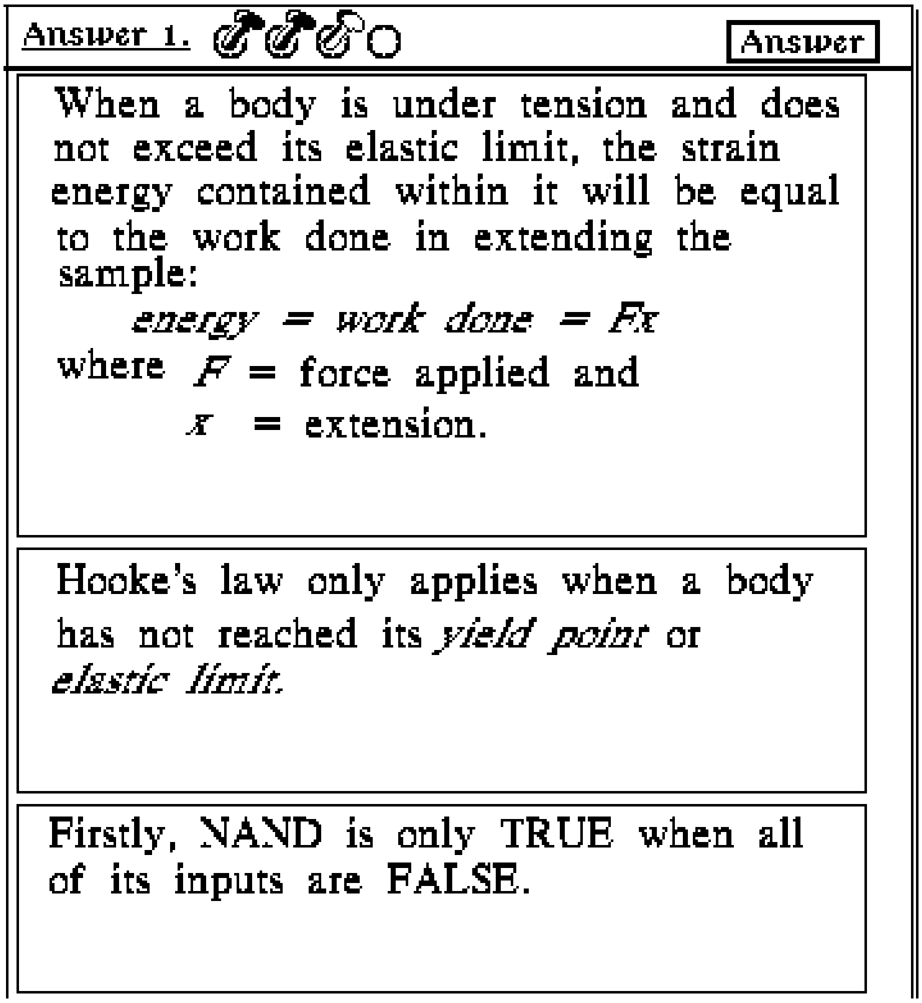


Figure 6.20: An incorrect fragment has been placed (white peg)

Once all of the correct fragments have been placed then the authored answer will be shown instead of the pegs. It is unveiled visually on top of any justifications on the answer page, thus temporarily obscuring them. Should the student turn to another page and then back again, the answer will have gone and the justifications returned.

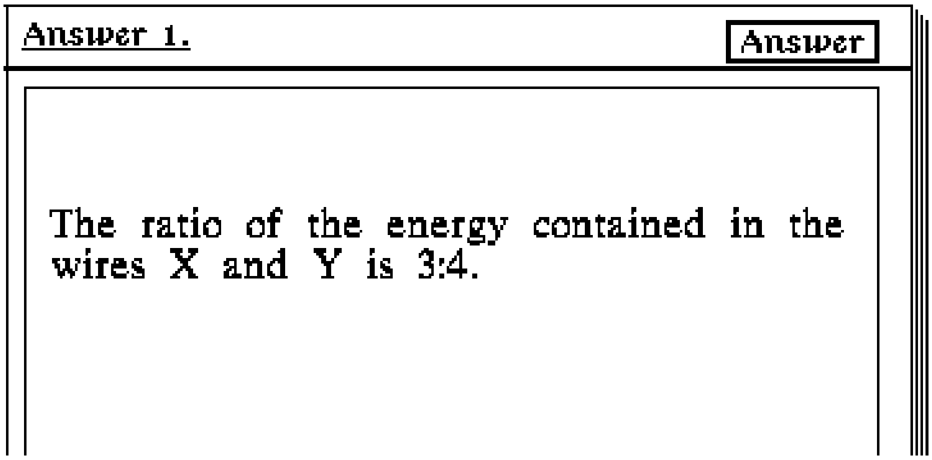


Figure 6.21: All the correct fragments have been placed. Answer 1 is revealed

6.3 Summary

The system implements an argumentative style of problem solving. This tutoring style relies on there being only one route to the answer. While this could be circumvented by allowing the author to generate more than one answer and reasoning thread, this would increase authoring complexity. Perhaps a sharply focused question with only one line of argument provides less obstruction to learning.

The mechanism requires a great number of justification fragments to be authored in order to *hide* a particular question's fragments amongst those fragments of other questions. Initially this may be difficult and the fragments may be sufficiently different to make them easy to distinguish. However if each exercise book contains questions of a similar nature then the text of the fragments will be similar. Therefore unlike traditional multi-choice authoring, the fragments associated with other questions act as distractors.

The minimal effort required to author justifications will not only improve the lecturer's questions but will enable others to use the same questions with impunity. The argument fragments effectively document the question and its solution. Nevertheless, it is also possible to use the system without arguments. In this case answer fragments replace the justification fragments and a congratulatory message replaces the answer. When the student has selected all the parts of the answer, and requested the system to check this answer, then the congratulation is displayed. Clues need not be authored at all. Although the teacher can use the system without justifications, the student's learning will be shallow. Furthermore, combining the two styles of use would be extremely unwise.

The dialogue with the system is artificial in the sense that under traditional conditions they would write free-text onto lined paper which a teacher would later assess. In this system, students must select fragments of a justification that they consider are similar or the same as some part of their solution, and these are placed in the exercise book. Feedback can be immediate since it is possible to determine the necessary assistance from student's partial answers. Such feedback would only be given if requested by students, when confident with their set of arguments. The fragments are individually enclosed in boxes and positioned randomly onto pages of a book of justifications. One book of justifications exists for each exercise book. Thus a student will not become overwhelmed by the number of justifications in a typical course.

Because the teacher's role in the courseware production process is now very high the course material can be easily maintained at the forefront of research. Only the course content is updated, the courseware books (the exercise book and justification book) are automatically generated from this. The material can also fit well into current teaching practices as it simulates a revision class.

The requirement to think about the reasoning for an answer suggests that deep learning will be achieved. The visual question and justification fragments will allow the student to cogitate as well as browse the course material. Learning is held at the core concept and the student cannot easily stray from this. The clues need only be spoken and are thus transient as they are provided simply to give the student essential vocabulary necessary to find the right argument. This will ensure that the student's focus of attention is not lost and a fixed goal is maintained for learning.

Finally there is no restriction as to the content of the question and justification fragments. Both text and diagrams can be used. Depending on the authoring skills of the teacher the content could contain audio samples, moving pictures, miniature simulations and so on, enabling the student to explore and discover features about the question's domain. However using dynamic multimedia for the argument fragments may well reduce the student's ability to search, study and browse them. Furthermore, as stated in previous chapters, over-use of a medium is dangerous to the practical adoption of any system by both teachers and students.

Chapter 7

Cognitive Perspective Analysis of OLL and HEART

The two systems presented in this thesis (on-line lectures and HEART) have followed a particular philosophy in their design. This philosophy suggests a teacher should be able to make good use of IT and students should have specific goals to their learning. Thus, the teacher will not be averse to using the system and the student will not be demotivated as they learn. The reason for implementing the on-line lecture system was because the lecturing medium is well understood and used very often. Teachers know how to develop lecturing material and students know how to learn from it. This is due to the experience of both users. By automating this lecturing style the benefits of a simple media and a simple mechanism can be analysed to see if they improve authoring styles. The HEART system took this a stage further to provide the role of a practical class demonstrator or coach. This is a role to which many teachers can relate and again students are familiar with the metaphor. Similarly this system aimed to be authorable yet be efficient and effective as a medium of learning.

The analysis will provide indicative results about the effectiveness of the systems to satisfy the requirements of a CBE authoring tool. That is, in terms of media usage and in terms of the teacher-student dialogue. By considering the systems in terms of their ability to satisfy these two issues the effectiveness of the authoring and learning techniques can be discovered. The proposed strengths of OLL and HEART are initially verified and those of HEART are then validated. This will highlight the usefulness of the guidelines for system development. These systems should be successful at generating hand-crafted courseware for deeper learning.

7.1 CBE Evaluation Methods

To study the systems it is plausible at this point to generate a summative evaluation; thereby administering and evaluating user questionnaires, tests and longitudinal studies[15,16,153]. This technique for evaluation is an obvious step as it confidently tests the authorability and levels of learning outcomes given a sufficient sample of users. The system must agree with the quantitative results discovered.

Evaluating how human beings make use of an interactive system and whether that system is fulfilling their requirements is extremely difficult. Typically a psychology experiment of such activity requires many participants and focused questions about the interaction which is being addressed[15]. Similarly, evaluating HCI requires observation of humans interacting with computers with questions that are specialised to reveal the effectiveness of particular interactive features. Methods for understanding what has been observed again require the observations to be focused and comparable throughout the test groups[154]. Test groups which are distinct are required to compare and contrast the differences across and within these groups. An understanding of the human psychology and sociology enables the results to be interpreted in relation to the human and their needs[16]. However, any educational environment also needs an understanding of the learning methods and teaching practices which introduces further areas of uncertainty in evaluations[155]. The comparison is not only of one person's psychology but of the interaction between two or more people. In CBE, the added complication of a computer intervening the communicating personalities adds further problems.

The difficulties encounted when evaluating ITSs have resulted in the development of an alternative proposition. Littman and Soloway[156] suggested a Cognitive Perspective for evaluating PROUST (an intelligent tutor which teaches bug-free Pascal programming to undergraduates). The methodology they use tries to discover above all: "What is the educational impact of an ITS on students?"[157] (p 462) Their focus on ITS may not be entirely necessary. Their argument was that a student model from the system could be directly compared against the real student's cognitive process. Yet, in their terms, CAI evaluation could be based purely upon whether students "respond correctly to questions"[157] (p 464) whereas an ITS is used to teach student's problem solving skills and knowledge. Yet cognitive tools for education which do not always utilise expert systems explore the student's use of active thought[10]. Any cognitive tool for education will have a model of intended student behaviour which attempts to improve problem solving knowledge. The design of hypertext as a cognitive tool, for instance, has adopted a model of how a student learns, i.e. the student can build knowledge from the information presented to them or from that which they already know.

Deeper learning requires active cognition from students thus it makes sense to analyse the two systems presented in this dissertation from a cognitive perspective. Thus what follows is an internal evaluation for both OLL and HEART. In addition an external evaluation, which is a user evaluation, has been attempted with respect only to the use of HEART by a small number of students.

7.2 Internal Cognitive Analysis

There are three areas of interest for an internal cognitive analysis. These are represented by these questions: 1) "What does the system know?", 2) "How does the system do what it does?" and 3) "What should the system do?" When analysing an ITS these represent areas of the final system which might be presented to the student. However, "What the system knows" simply asks about the knowledge base developed by the educationalist. "How the system does what it does" asks about the mechanisms developed by possibly another educationalist. Answering the final question, "What should the system do?" requires the educational research that has been studied and applied to be analysed.

In OLL and HEART the first area is addressed by the tools which are used to author courseware material. The courseware creation and organisation is the knowledge base of what the system knows. The second area is satisfied by the techniques which are used to provide a dialogue between the teacher and student via the CBE system. The dialogue is a means of ensuring that effective interaction between the teacher and student exists to form the basis of deep learning. The last area is defined by the overall educational method of the systems. That is, the method by which the teacher teaches. For OLL and HEART these are the lecture and the problem class. Both systems should be as educationally beneficial as the traditional methods. In OLL and HEART, the mechanism has already been decided and is not defined by the author. As a result of the protocol for authoring system design, the teaching mechanism is constructed by the designer and the teacher must conform to this style.

7.2.1 OLL Analysis

What the OLL system knows is based upon the material which is produced by the teacher. Thus the tools must be both familiar and usable without the need for lengthy tuition. The OLL system has tailored the Book Emulator's functionality to focus it towards traditional lecture production. The primary feature of OLL has highlighted the notion that lectures are made of *content* which is presented according to a predetermined *plan.* The **layout** of the lecture and a **specification** of the presentation plan has been separated into two areas of the basic BEM metaphor. Thus the user initially has two degrees of freedom. These are: i) simply use OLL for lecture slide layout, and ii) add the presentation plan to the layout to form an autonomous representation of the original lecture. Although the distinction has been identified before, OLL has accurately separated them using a simple metaphor. In Authorware[67] for instance, the specification and layout are distinguished yet the layout is dependent upon the specification. The metaphor for specification is a flowchart of the sequence of events. The relationship between the flowcharted "program" and the layout is not as well defined as with the slides in OLL. The layout is generated by having elements in the flowchart invoke the layout to be displayed.

Once the lecturing "knowledge-base" has been produced the student must be able to use it for learning. The on-line lecture system emulates the lecturing style of teaching and learning. This is a familiar environment where a familiar dialogue can be achieved. By comparing OLL with lectures it will be possible to identify how both mechanisms "do what they do."

In assessing an environmental dialogue for computer based education it is useful to consider Laurillard's guidelines (discursive, adaptive, interactive, reflective)[19]. However these are based on ensuring a good overall learning environment and lectures are not meant for focusing deep learning. Conventional lectures and OLLs are only discursive. This is in common with all of the IT-based presentation systems which have some mechanism for allowing any user to view the course material. The on-line lecture has the possibility (more than a conventional lecture) to be individually reflective. A student has access to material for review on more occasions than just the lectured time. The only opportunity for this to occur with a traditional lecture is for an audio recording to be made of the lecture to supplement lecture slides. The audio will narrate the actual lecture slides to a student after the event[131] (section 8).

How the OLL does what it does is educationally no worse than a real lecture. The act of pressing information into the long-term memory by using lectures and static resources does require the student to be able to review and make notes about the information. The student must later actively consolidate the information into a form which they can absorb from the prepared and annotated material. Like a typical lecture, on-line lectures do not promote interactivity and the adaptability which goes with it. At its simplest level (the level used by OLL), the lecturer can still interact with the audience. The lecturer simply responds to requests to review material or pause for contemplation. The lecturer might even utilise optional material to elaborate upon what has been said. OLL can afford these requirements by using step-back, play-and-stop, and hyperlinks.

The teachers and students have little influence over what OLL should do as this is the educational designer's role. Lectures should transfer information rapidly and effectively into long-term memory for rote recall. Nothing more than what is taught can be expected to be comprehended without further tuition. OLLs do not promote a dialogue for deep learning but like a lecture they are a medium for good course generation and exposition. Depending on the teaching abilities of the lecturer they will provide the functionality required of the common lecture. Computer literacy is not a main requirement.

OLL is not a full educational tool because little cognitive activity is necessary. There are no challenges enforced and no rewards are guaranteed. OLLs cannot be adapted in the same way as real lectures. This is not necessarily to the detriment of the OLLs because it does force the lecturer to be prepared and methodical. It was never envisioned that OLLs should be used as highly interactive forms of tuition but as a method of delivering hand-crafted information.

7.2.2 HEART Analysis

The HEART system knows the parts of an argumentation sequence required to solve given problems. These components are a question, its sample solution and the final answer. The only other fact is the relation between these components.

Little knowledge about user interfaces should be required to generate this information in HEART. The text and graphics are authored in a linear fashion and the identification of the components is marked in the margin. Although other interface authoring styles exist for creating the same information, the closest mechanism to the HEART system is HTML creation. In this case the markup is to indicate document presentation variations rather than knowledge representations. Alternative systems of component markup allow a component frame (incorporating text and/or graphics) to be given an identifying key. These frames can then be sequenced according to their keys afterwards[68,107].

The construction of the knowledge base in HEART is more than just markup of material by the teacher. Authors require tools which will assist them in generating good argumentative questions, answers and solution tracks. HEART has a simplified form of knowledge base that does not require logical inferences to be encoded. The knowledge base already contains these constructs in the way in which it is captured. The teacher knows that the associations between the authored components follows an argumentative sequence. To the system this intuitive sequence is more useful than linear associations. The in-built argument sequence can be interpreted by the tutorial system. Classifying content has been used for ensuring the optimum design of hand-crafted tutorial material[121] but not for coordinating the exposition of the material later. The design of HEART assumes that the teacher knows how to generate suitable content. If they do, then the system will teach as the author intended. However the structure of information required by the system is not commonly related to a teacher's current practices. Examination style questions, and their sample solutions can take many forms. The methodologies used for the production of sample solutions are generally ad-hoc. Any guidelines for ensuring that comprehensive solutions are generated are seldom followed, if understood at all. Usually there is enough room left for a teacher to apply heuristics when attributing marks to a student's solution. Furthermore, no single answer is necessarily the only solution to an examination style question.

As the OLL system has shown, the important issue for a good tutoring mechanism is to promote valuable communication with the IT media. This means that the courseware should generate an involving teacher to student dialogue. But the dialogue must be captured within a familiar teaching practice. The HEART dialogue aims to encapsulate activities such as thinking and discussing with peers, or to motivate practice of the concepts individually.

HEART does what it does by following a simple goal-action-feedback cycle. This is encapsulated in a teaching practice that allows students to think actively and discuss with peers. The teacher's dialogue is one of recording explanations and justifications, whereas the student's is one of searching for these explanations and justifications. This search is primarily in their own understanding and the associated conceptual network. Unlike other cognitive-based CBE systems, the dialogue of HEART is not represented in a pseudo-intelligent manner. Neither is it reliant upon students creating conceptual maps on the computer for themselves. In contrast, the course teacher has an active (yet physically remote) role in the students' learning activities. The teachers provide the necessary dialogue for initiating a goal, focusing activity and providing feedback.

Goals

The advantage of an examination style of question is that the goal is made specific and succinct. Little margin is left for unanticipated misinterpretation by the student. The goal must be observed and understood by the students. Their dialogue will require that they can orientate themselves and clarify what is required of them. In HEART this is achieved by giving them access to clues and reference material which can put the question into context should the student require it. Of course, the question could contain this material but the students may become unfocused from the question if contextual information is made explicit. HEART does not explicitly require the teacher to generate this part of the dialogue. Thus a student will not always have access to it. However, the environmental context in which a goal is set can provide this information. In HEART the exercises are in a book of similar exercises. In other tutoring systems, the exercises will exist with a course module or a course of contemporary modules.

Actions

If HEART is going to be beneficial to learning outcomes, it must adapt to student activities to give instructive guidance. The HEART dialogue will guide towards solutions through clues and hints either in the question or explicitly designed for each fragment of a solution's argument. Although the support is not intelligent enough to judge the students' conceptions it is aimed to feed the students' needs for elaboration.

The main method by which the student interacts with HEART is via the placement of justification fragments. The student must plan a solution in order to find the evidence (in the form of fragments) which they require to describe their solution to HEART. Searching for evidence is analogous to library querying. Library queries require the fragments to be catalogued in some familiar manner, (e.g. AI, Graphics, Languages in computer science). Fortunately, each text book in HEART represents its own categorisation therefore material should be simple enough to discover when the fragments are unique.

Nevertheless, this does show that the mechanism cannot be used by a student to revise about one particular procedure. The procedures for all the questions would be similar thus their fragments would be hard to discern. This is a double edged sword since fragments need to be hard to discover to avoid just guessing, but easy to find if you know the answer. Only if solutions to questions in the text book are sufficiently different will the system be usable. It is traditionally common for one exercise book to contain similar exercises to give a student a lot of practice at particular procedures. There is no evidence to suggest that a student will not easily discern the difference, notice the common theme and thus learn the procedure more accurately. This may mean that less practice is required and ensure that a deeper understanding will be achieved. This kind of evaluation has been beyond the scope of this dissertation.

The HEART dialogue mechanism is utilised as a **revision tool.** The student must know the course prior to the question being asked. They can then use this knowledge to assist them in searching, selecting and placing justification fragments. This contrasts with an alternative mechanisms which could **coach** students. The coach provides a question and the full solution. The student could browse through the tutorial material to see how the teacher attempts to solve an exercise and to see the reference material they would use.

Feedback

In the end, a teacher must generate the dialogue component which will consolidate the material presented so far. This represents the satisfiers and feedback which will enable a student to complete the tasks required of them. The HEART system requires the teacher to author this final conclusive statement for the answer based upon the judgemental factors. The statement will satisfy the reflective needs of the student. The teacher need not encode a correct answer detection strategy. The system already detects correct answers from the students' dialogue via the fragments already authored. That is, once all the required fragments have been placed the correct solution must be know to the student. The authored solution is for consolidation purposes.

Consolidating components to CBEs try to detect errors and correct the student where misconceptions are found. A demonstrator will consolidate the problem by helping a student to reiterate what has been learned. The act of reiterating will further deepen the understanding. HEART preserves this reiteration by explicitly forcing students to describe their thoughts. The system confirms their overall solution by providing an answer which summarises the argument.

HEART cannot provide corrective feedback to guide a student away from misconceived solutions. It can only provide the raw material by which the student can derive correction for themselves. However, the solution is promised to hold a summative solution which will adequately consolidate and confirm their thought processes. To give them on-going guidance, the peg mechanism should allow the students to judge their progress and give keys towards the required solution.

7.3 External Analysis of Students using HEART

A large-scale investigation of the claims made by the thesis is beyond the scope of this research. Nevertheless, a small-scale study will better inform the discussion and provide some independent evidence concerning the validity of the ideas proposed by the HEART system. The following section describes such a study which aims to introduce evidence that may or may not support the HEART mechanism for encouraging students towards deeper learning. The first stage in preparing for any experiment is to define the hypothesis that is to be tested. In this case, it is: "Does the HEART system provide a suitable environment for improved deeper learning?"

7.3.1 Method of Investigation

In order to confirm the hypothesis from the evaluation, a number of methods of investigation need to be defined. Three forms of investigation were carried out within the study. Firstly, the students' opinions were gathered, secondly their activities were observed and recorded, and lastly experimental data was collected for statistical analysis.

To gather user opinions two questionnaires were produced (appendices A and C). The first asked a variety of questions concerning the students' attitudes to learning and the second questioned their opinion of the system. The student subject would circle the most appropriate response to each question. In addition, three open-ended questions were asked after the experiment to gain wider opinions.

To observe student behaviour, the experimenter spoke to each group for 5 minutes during each session. The discussion was general in order to draw out any unanticipated issues but focused on deep learning so that supportive evidence could be gathered. Lastly, while the students were using HEART their activities were recorded. This data provided the time to complete the task, the number of attempts at each question, the number of clues observed, any queries made, and so on.

The external analysis observes a Cognitive Perspective[156] which suggests that five considerations will develop a method of evaluating the impact on learning. These are: i) Cognitive Model, ii) What's Hard, iii) Learning Model, iv) How to Test, and v) External Evaluation.

i) Cognitive Model

Firstly, each student was given a pre-experiment questionnaire (appendix A) and knowledge test (appendix B). The questionnaire asked the students about themselves to ascertain their cognitive model. The knowledge test consisted of three multiple choice questions which could illustrate each student's understanding of the test topic. These were collected before the experiment began.

The students in each session were given a 5-minute instructional period where the experimenter described how HEART was used and with what it aimed to assist them. Thus all of the students had a rudimentary understanding of what was required.

ii) What's Hard

The subjects were first-year undergraduate computer science students. They had all revised and taken an examination several weeks earlier on the subject of digital circuit design which has a sub-topic entitled "Hazards." The experiment aimed to use HEART to improve the students' deeper understanding of "hazards" in circuit design. Historically, this topic has been found particularly difficult to grasp whereas it is fundamentally simple. The test groups were restricted to 30 minutes within which to complete the 7 questions in the HEART system.

iii) Learning Model

The HEART system aims to improve the depth of understanding of students by enforcing a cycle of goals, actions and feedback. Thus the goals should be noticeably observed by the students. The students should be able to make use of the operations and actions in order to reach the goals. Finally, feedback ought to indicate how distant or near the student is to their required goal. The observation of these properties will provide some insight into how well the students have followed a deeper learning strategy.

iv) How to Test

When the students were finished they took the knowledge test again followed by a post-experiment questionnaire. The students had not been told of a post-experiment knowledge test so that they would not attempt to revise simply for the questions they had been given earlier. This attempted to see if their articulation of the topic had improved. The post-experiment questionnaire was used to obtain the students' opinions concerning HEART. The time taken to complete the experiment also provided information about each groups competence.

v) External Evaluation

In addition to the observations above, a number of comparative studies were made. The students were placed into single or partnered groups randomly after they had been taught to use HEART. These groups consisted of only one student (singles) or a pair of students (partners). Thus the students using the HEART system could be analysed in terms of the tutorial support and the level of interactive dialogue. In addition, the information recorded about the the students' personalities and prior knowledge allows the results to be compared realistically.

Experimental Errors

After the experiment, one unforeseen error with it was discovered. Namely, the clues for the questions had been wrongly positioned during authoring meaning only one clue per question would be identified when a clue was requested. It should be noted that all authored clues were visible but their association to a particular questions was not expressed. A student could have easily browsed the clues during the experiment.

7.3.2 Results

The results of the pre-experiment questionnaire highlighted that the students were generally deep learners as well as motivated towards digital electronics. Yet most of the students could not clearly express how well they understood the course material for this experiment.

Question	Rating					Statistics	
Number	1	2	3	4	5	Mean	S.D.
3:	3	4	3	6	2	3	1.33
4:	0	1	2	10	5	4.06	0.80
5:	4	10	2	2	0	2.11	0.90
6:	1	1	9	7	0	3.22	0.81
7:	3	5	4	5	1	2.77	1.21

Figure 7.1: Summary Table of Pre-Experiment Questionnaire

The knowledge test showed clearly that many students found it difficult to describe a hazard and use a Karnaugh map. Yet most could spot a potential hazard in a circuit. Therefore, they understood how a hazard was formed but not how to correctly analyse a circuit or describe the conditions that distinguish static and dynamic hazards.

During the experiment the students quickly adopted the interaction required for the HEART mechanism. None complained that they had no idea what was expected of them. A few were unsure quite which pegs meant right and wrong and that in future a cross and tick might be more intuitive. The recorded data showed that in most cases the students quickly read the questions, browsed the fragments and placed the correct justification immediately. The experimenter observed that the partnered students entered into a dialogue in which they appraised a fragment before placing it into the exercise book and testing the answer.

The clues were seldom used by any groups, and only to solve the hardest questions. When a question became hard, such as questions 5 and 6, the students viewed the clues. However due to an error there was seldom a useful clue highlighted for identifying a missing fragment. As some subjects pointed out, if the clues had been authored correctly, the correct clue would most likely have provided the necessary vocabulary to answer the question. During later sessions the experimenter indicated any necessary clue to the subjects and they did find the vocabulary useful. The fragments' wording was made clear and a correct choice could be made from those fragments which were possible solutions. From the log of interactions, the students in difficulty would begin a trial-and-error process of elimination. They would place a fragment which was possibly correct and then ask for an answer. It can be noted that none use a methodical approach in order to ensure an answer would eventually be reached. Only one group gave up on the questions for which they could not find an answer. They complained that on one occasion more than one fragment could satisfy the system for the intended question. A fragment which acted as a distractor in one question could correctly answer another. This highlights a problem with authoring many similar fragments.

Question

```
In order to reduce the possibility for a hazard, what
are the different approaches you need to consider?
```

Possible fragment

```
Choose all prime implicants since they cover all input
conditions.
```

Actual fragment

```
Of all the prime decoders, at least one must remain
true.
```

Figure 7.2: Question and the two possible fragments

After the experiment a slight increase in the score for the knowledge tests was recorded. The students had made a slight improvement in their understanding of what distinguishes static and dynamic hazards. All the partnered groups took the least amount of time to finish all the questions. This tends to hint that discussion was guided successfully towards arriving at the actual solution quickly.

Subject	1	2	3	4	5	6	7	8	9
Group No.	1	3	2	2	4	5	5	11	11
Pre-Score	11	9	14	8	13	12	10	12	13
Post-Score	11	11	13	14	12	15	13	14	13
Difference	0	2	-1	6	-1	3	3	2	0
Time (mins)	25	28	20	20	17	24	24	15	15

Subject	10	11	12	13	14	15	16	17	18	Mean	S.D.
Group No.	6	6	7	8	9	9	10	10	12		
Pre-Score	11	14	14	14	9	12	12	4	13	11.4	2.6
Post-Score	13	14	12	14	12	12	11	9	14	12.6	1.5
Difference	2	0	-2	0	3	0	-1	5	1		
Time (mins)	27	27	26	24	22	22	30	30	46		

Figure 7.3: Change in Knowledge Test Scores

From the post-experiment questions only three were significant (questions 1, 5 and 6). These confirmed the observations that were being made. The students quickly learned how to place fragments (Q:1) and hence know the goal which was required and how to get to that goal. Secondly, the fragments were understandable for solving the questions and were as the students expected (Q:5). This means that the actions and resources that the subjects were given could be used to reach the goal that had been set. Lastly, the feedback in the form of pegs was good for identifying when a solution plan was right or at least leading in the right direction (Q:6).

Question	Ratings					Statistics	
Number	1	2	3	4	5	Mean	S.D.
1:	14	4	0	0	0	1.22	0.46
2:	2	0	12	4	0	3	0.84
3:	1	7	2	5	0	2.73	1.03
4:	1	4	13	0	0	2.67	0.59
5:	0	2	2	4	10	4.22	1.06
6:	8	8	2	0	0	1.67	0.69
7:	0	5	6	6	1	3.17	0.92
9:	0	5	10	1	1	2.88	0.78

Questions 3 and 9 had three and one blank responses respectively.

Figure 7.4: Summary Table of Post-Experiment Questionnaire

The open-ended questions revealed that many students found the system useful for its intended purpose, i.e. revising. Yet, some method of marking their prior (incorrect) answers was required. This might be in the form of a history of the recently used fragments, for example. This kind of feedback is not advisable since students would be even more inclined to guess at solutions rather than think about the correct solution first.

One particular subject (number 2), a serialist and lone worker, took a long time to get to grips with the system and found question 7 extremely difficult. However the subject persevered until the experiment was complete. The subject's attitude towards studying hard with the system paid-off because the subject's post-experiment knowledge test score was higher than the pre-experiment score. For this subject the system satisfied their desire to work through problems stoically.

Group 11 was the quickest to complete the test. Subject 9 (one half of group 11) was also a serialist learner. The subject considered itself to be well revised for the experiment and it obtained a high pre- and post- knowledge score. It only found question 4 hard. Therefore it is probable that well revised students will quickly progress through the system.

All subjects bar one scored highly on the post-experiment test. Thus the system either jogged the memory of the students, or it taught them enough material to raise their scores. Even the one poor subject made a 125% increase on their pre-experiment score. Unfortunately most subjects did not report a significant change in the way in which they would learn in future. Furthermore they did not appear to **think** as opposed to **read** solutions to questions any more than usual. This may simply be because generally the students in the experiment already revise the procedure for reaching results to questions and do not just read answers.

A suitable measure of a student's deep understanding is difficult to find. Perhaps students' memory of information after a long period of time would determine this. Alternatively, the students' ability to answer the knowledge test (which was not directly related to the experimental questions) shows their deep understanding of the topic. Perhaps, the marked (but not statistically significant) increase in the students' post-experiment knowledge tests shows a deeper understanding.

7.3.3 Summary

In summary, the HEART system experiment appears to show that students found it useful in improving their revision. It provides much of the necessary information for understanding the reasons that go into finding the solution to a question. The students remarked on this factor. However, whether this environment improves their deeper understanding of a topic is less easy to determine. The post-experiment results point to a better understanding but not significantly. Only a more thorough educational examination will give a better picture of the students' deep learning. Yet this small study suggests that in the short term there is an increase in the students' ability to solve questions based on a topic authored within HEART. Concerning the usage of HEART, students have no conceptual difficulties. The feedback (pegs) appears good at giving the students enough information to resolve the necessary fragments. Likewise it does not seem to give too much away so that a guessing strategy can be employed. In fact, the students asked for more information to be provided to assist their guessing.

7.4 Conclusion

A cognitive perspective analysis was carried out for the tools developed for authoring in the two systems as well as the mechanisms for education themselves. A long term study of the usability and effectiveness of the two educational styles proposed by this thesis would yield empirical results. The short term study only hints at these results, but it does provide some data concerning the HEART educational system. This chapter has verified the implementations of OLL and HEART and validated some of the issues raised by HEART.

The OLL system has been specifically designed to make use of a minimum number of features. This has resulted in no lack in functionality necessary for creating common forms of lecturing. By separating the content of the lecture from its specification the presentation and plan need not be constructed at the same time. Thus a novice OLL user can quickly produce familiar lecturing slides. As the user's experience increases, more functionality can be adopted. This learning curve is very easy. By allowing text, audio and graphics to be integrated from other tools OLL allows computationally experienced users to include material from advanced sources. The advantage is the intuitiveness of the OLL technique.

During private study, the student is in control of the sequence of learning from the lecture. They can use the preview and review buttons to step through the course or use the page turns to jump straight to material they wish to see. Yet for a teacher during a lecture, these on-slide buttons will not be as useful as the physical hardware. The most intuitive device is the 35mm slide projector controller.

The HEART system enables a teacher to structure information without the use of a typical menu hierarchy, a flowchart or a traditional scripting language. The structure is implicit in the design of the system. It requires the teacher to follow a rigid style in the material they create but the style is familiar to current working practices i.e. examination questions and sample solutions.

The small-scale study of students using HEART revealed that students can practice what they have learned and gain feedback as they work. The clues and hints were seldom used in the experiment but the lack of a relevant clue for some questions shows that these still have a strong role to play. The feedback which was provided in the form of pegs appeared very useful and thankfully did not act as an aid to guessing. The reactive intelligence it offers, although not guaranteed to be optimal, does assist a student's path to a solution. All the partnered subjects improved well and generally took much less time to complete the experiment than the single subjects. The dialogue in which students engage was broad and active as anticipated. Plausible fragments to the questions were appraised before they were tried. Only as a last resort was guessing attempted. Even this was informed experimentation.

This argumentation system will not solve all the problems encounted during learning. Students still required some help from the demonstrator to provide solutions to complex misunderstanding. Nevertheless HEART promotes the need for students to acquire an ability to learn well by learning to help themselves. The technique for finding justification fragments is very simple. Yet it did not appear in the small experiment that any search mechanism was required. In a larger system the ability to pose querying hypotheses to find fragments by using more information than just keywords could still be beneficial. However the impact of this must not affect the simplicity of final courseware construction.

Many of these issues have been highlighted by investigating the systems in relation to: their use of media through what the systems know, the dialogue they describe through how the systems do what they do, and the educational design through what the systems should do. By focusing on these areas together CBE systems that hand-craft courseware for deep learning can be developed. By ignoring any of the areas, the learning outcomes will results from unmotivated activity, that is, activity which has no goal, no actions *or* no feedback. With the external analysis the outcomes appear promising but these could depend upon the students' aptitudes and motivations[158,159]. In the experiment, these were favourable towards the course topic.

Chapter 8

Conclusions and Further Work

The research, designs and analyses that have been discussed in the dissertation are summarised in this chapter. Each stage of the development is focused upon to identify the conclusions drawn. The contributions to knowledge are clarified including the publications that have been generated. Lastly, propositions for future work will be described.

8.1 Conclusions

> "Teaching must create a learning environment in which the complete collection of mathemagenic activities is available, and their unity preserved at every level of description of the learning situation; i.e. conceptual structure, actions, feedback and goal must relate to each other so that integration can work." (pp 93)[19]

This dissertation has aimed to discover whether deeper learning can be promoted by using courseware that has been hand-crafted with a computer. Courseware is for use by educationalists in the classroom, so the hand-crafters are the teachers and not the IT specialists. Thus the class-teacher must create the mathemagenically complete learning environment.

It was necessary to discover the requirements which promote deeper learning. In doing so, the focus was upon how a student can be kept motivated during the learning process. The conclusion was that a student must be able to satisfy 3 stages of learning (3Ps) as pointed out by Child[7]. This relates closely to the requirements necessary for motivation as stated by Keller and Suzuki[55]. It is necessary for a student's attention to be grabbed, for material to be made relevant, for practice to build confidence and for feedback to generate satisfiers. This sequence will provide positive conditioning towards future learning. A motivated student will be active towards learning. Activity and motivation encourages deeper learning. However, deeper learning will rely on the students' approaches to the environment. The teachers must provide instruction which will meet these student requirements. Structured and sequenced prose and tutorial course material will be able to reinforce motivation during the student's learning. The aim of teaching is to prepare an instructive dialogue which will subsequently help students to communicate with the learning environment, either passively, when using a book, or actively, when practising with an experiment. The dialogue must be discursive, adaptive, interactive and reflective for the student to be fully satisfied.

For a teacher to support the educational dialogue required by students, two mechanisms are available through IT. Firstly, the teachers can be automated by recording all their knowledge onto the computer. Secondly, their knowledge can be transmitted across long distances to many destinations as information. Both of these mechanisms need to preserve the educational dialogue intact. Prior systems have attempted to implement these styles. However, the deeper learning dialogue is satisfied through student activity alone. Motivating that activity usually requires the teacher to interact with the student through a communicative dialogue. The dialogue can be administered in several forms, from AI to simulations and from well-written tuition to cognitive tools. To encode this interaction with an automated system is very difficult yet ultimately very useful. The effectiveness of hand-crafted automated tutorial mechanism relies entirely upon the programming experience of the teacher. Otherwise it relies upon the ability of the teacher to describe their requirements to a programming team. This latter solution is costly and prone to errors.

Although systems for deep learning do exist (through cognitive means), they have seldom *and not successfully* done this through courseware authored by the teacher. Teacher authoring can be applied to deeper CAL but requires two issues to be satisfied. Firstly, the IT metaphor for an educational media must be familiar so that both the teacher and student can relate to it. The authoring tool should aim for computer-novice teachers to author their own courseware within the metaphor. In HCI, systems which use direct object manipulation and visual schematic descriptions appear to be most accessible to users. Secondly, the features of the dialogue between the teacher and student must be retained across this medium.

This is maintained through the optimum design of computerised educational environments.

The concepts of HCI are utilised to highlight the design requirements for a medium in education. CBE concepts provide guidelines for the computer-based mechanisms available for education. In theory, the educational forum and strategy can be defined so that it is possible to craft a cycle of education that will result in a deep learning dialogue. It was necessary to create a protocol for the design process of an authoring system that aims to promote deep learning.

By focusing on these two aspects of hand-crafting education it was hoped to be able to create motivating IT environments for deep learning. The first aspect is the use of a familiar media. This prompted a system to emulate the lecturing medium. The projection of a computer display is familiar to a student who has experienced OHP tuition. The displayed material for an OHP lesson has the advantage over the blackboard that it can be prepared in advance and shown directly. However, the computer projected image can also be animated. It can be automated to replay the lecture when unattended by a lecturer. Unfortunately, without interaction from a real tutor high learning outcomes cannot be obtained by any form of mass tuition. The main aim of on-line lectures was to ensure a lecturer could use a computer efficiently for preparing lecture-like material and gain the advantages which it offers.

The second aspect is an educational teacher-student dialogue. This aimed to be motivating through remaining relevant to student needs. Learning for examinations is already very motivating as students have all the right prior knowledge and goals. However, revision usually takes place in tutorial or study classes with intelligent assistants. The use of AI was not possible if the material was to be hand-crafted. Hence an approach using an alternative cognitive strategy was devised — that of argument building. Teachers build reasoning during tutoring in order to explain the solutions. Similarly students must create arguments which are plausible. As students revise with peers they question their own knowledge and the procedures to find solutions. They argue through their own solutions with others to gain a deep understanding. It is a subtle way of getting a student to "lecture" the course for themselves in order to learn. Therefore, the task is familiar to teachers and students but the methods for achieving useful results is not familiar. The task for the teacher which appeared to be useful was examination question and solution generation. The student is already able to make use of examination style questions during private study.

Both of these methods were found to satisfy the requirement for which they were designed but not a combination of the two. On-line lectures (OLLs) are an accurate imitation of the lecturing media but the dialogue which lectures provide does not guarantee encouragement towards deep learning. OLLs represent the efficient mass dissemination of knowledge and not the long term memory retention of concepts. However, programming ability is not the problem. The lecturing ability is the overriding factor. HEART satisfies the deep learning environment but prior knowledge is required. The learning environment of HEART is not directly familiar even though it follows an examination question metaphor; this is due to the use of justification fragments. For the author, the construction of examination arguments is generally approached in an ad-hoc fashion. The structure of arguments is not readily authorable to demonstrators because they often develop arguments according to necessity in the problem class by drawing upon their own expert knowledge. To take this medium and put it onto a computer requires the demonstrator's authoring role to be formalised so that it can be captured. The technique employed by HEART aimed to be simple and it was very linear, thus matching the lecturer's style of constructing examination questions. However, this identified the shortfall of lecturers' course construction techniques. Nevertheless, a step forwards has been taken into hand-crafted tutorial material. The student interaction with the system has been shown to be simple. Students worked discursively when trying to vocalise their understanding. Guesswork was minimised yet feedback for their solutions was satisfactory and encouraging. As an aid to studying, HEART seems to maintain students' thinking about solutions to problems.

8.2 Contributions to Knowledge

This dissertation has shown through research a novel approach for designing CBE. Two distinct approaches have been followed in the past for improving the educational value of courseware. Firstly the teacher's access to courseware production has adopted technological advances. For example, hypermedia and multimedia authoring systems are being developed and improved. Secondly the systems have adopted techniques which will improve the students' deep learning activities. For example, intelligent tutoring techniques and cognitive tools have been improved. It has been argued that these two approaches have never been combined to allow teachers to produce courseware which encourages deep learning activities. It has also been argued that by focusing upon these two approaches independently the systems are insufficient for practical use in educational establishments.

To ensure that these two approaches can be combined successfully, a new design protocol for CBE authoring systems has been devised. This ensures that the usage of media and the dialogue mechanisms are appropriate for authoring and ultimately for educating. Developing familiar media on IT and ensuring that a deeper learning dialogue is used improves the practicalities of future CBE systems. Without this model, designers will generate mechanisms based upon IT/programming metaphors which are difficult for IT novices like teachers and students to use. The excuse that IT literacy is a problem cannot apply in an industry which will not obtain immediate gains from the processing power of the computer. Education does not benefit directly from number crunching but it can benefit from information technology that makes use of practical interactive metaphors.

The two systems developed to investigate the design protocol show that it is possible to consider the two approaches to CBE design together. That is to the extent where authoring is simplified to a level where the lecturers would be willing to create the bulk of the courseware themselves. This willingness also originates from mechanisms which are as effective as alternative, yet traditional forms of communication.

On-Line Lectures

On-line lectures have identified that layout and specification should be made visibly identifiable and comparable. Alternative approaches tend to hide the definition of a specification from the user, perhaps in a function (either a built-in or user-defined program script) which controls a frame of the content. Otherwise the specification is made wholly explicit to allow any form of interaction to be defined. Such as with a programming language (either textual or visual) that co-ordinates the display of pre-recorded images, text and sounds, or generates them automatically. The novel approach taken by OLL separates the two components into two areas of construction which can be compared through overlaying.

Hand-Crafted Argumentation

A deeper learning environment can been achieved through hand-crafting argumentation. The value of using argumentation to develop problem solving skills has been realised before but not the opportunity for utilising this technique to encourage deep learning in CBE. A practical and novel technique for authoring arguments utilises the examination question construction metaphor. The hand-crafted problem solving exercises are in a form that requires a computer to mediate the activities. Without the computer, the querying dialogue can not be supported automatically.

Although the design protocol seems as though it steps away from utilising IT to improve education, it is a step towards making CBE usable for education. The concrete design of CBE systems in a familiar framework that uses effective teaching mechanisms will provide CBE with firm foundations upon which to develop more processor intensive applications. Teachers cannot be expected to learn ever-changing computer technology. With familiar media they will feel motivated to learn useful and improved course creation techniques. As currently unfamiliar techniques become familiar, courseware production media and mechanisms will develop. Until this is the case, CBE developments in both authoring and learning will be impractical.

8.3 Future Work

Imminent work

The obvious next stage is to modify the questioning mechanism which the student uses in HEART. Rather than use a search facility, a better dialogue could be devised. One which enables the student to "discuss" with the system in some familiar and analogous manner. Perhaps the system could use a simple Eliza[160] or SCHOLAR[62] mechanism to draw out a student's understanding generically like a good demonstrator without the use of complex AI. Alternatively, a metaphor closer to library working could be developed to allow students to have coursebooks available as they use HEART for learning. Ultimately the dialogue needs to be intuitive.

It is also necessary for more work to be done in structuring the media of the tutorial. This allows the teaching to be thoroughly organised and presented in ways that promote deep learning. By improving the traditional mechanisms to be more efficient they can be transferred to a computer medium which a teacher can adopt. Design rationale[148], concept mapping tools[10] or instructional design methods [53] might be useful in assisting the teacher to create argumentation. Yet, if the technique moves away from intuitive methods of construction, then the system will suffer. But if the basic principle of tutorial classes and laboratory sessions is flawed in its execution then the system will also be flawed. Only if teachers improve their tutoring style will learning outcomes be improved. The HEART system can take a step towards this by assisting and encouraging more efficient tutoring preparations. In addition, it could be possible to examine how tutoring styles affect argument creation. Proponents of activist, reflective, theorist and pragmatic learning styles[104] may use the simple argument structure of HEART in completely different ways.

Lastly it is feasible, once the system improvements have be made, to carry out further external evaluations of the system with real teachers and students. Both teachers and students have an opportunity to contribute to the evaluation of the systems but this will take time and resources. It is important to ensure that the evaluation is able to discover these 3 issues:

i) The HEART system is no worse than the traditional technique.
ii) Learning outcomes are a direct result of the CBE system and not the new environment in general.
iii) Motivated learning is evident due to the techniques employed.

Long-term goals

It should be possible to take the authoring system design model to a state where systems will all have to follow the protocols in their early production stage. This will mean that more development time can be spent in ensuring that a useful array of tools will be available for the teacher. In addition, the courses which are produced using these tools will actively engage the student in dialogues which interest them. The design of these dialogues will define the sort of information which must be authored. Thus the teacher will not have to worry about creating interesting educational environments for their students via a computer. The system will already have defined that interaction. The teacher need only worry about the content of the courses. This content will not appear to require further information other than that which is topic-based. As teachers become familiar with authoring mechanisms, the insertion of control information will be as natural as adding punctuation to writing or layout (titles, lists and page-numbers) to over-head slides. This is exemplified in the margin-markup used in HEART and the symbols used in OLL.

For the students, the system will be similarly as intuitive. They will be able to browse, study and query the information that they are presented. However, the material will be interesting and encourage activity rather than require this activity to be invoked entirely by the student. HEART has appeared to satisfy the students' desires to argue their understanding. This is made available through relevant examination style questions. Future learning environments will pose enough course material to satisfy the student and then it will assess their requirement for more information. This again will be presented in a way which will interest the student.

To achieve this goal will require investigating further the use of cognitive and intelligent computer models, tools and systems. Yet, rather than take this investigation in isolation, the information that these intelligent systems can use must originate from the course author directly. Hence, the structure of information must be consolidated to such an extent that a novice teacher can develop with it. Structuring knowledge must not make gigantic leaps, but each step should be sufficient in satisfying end-user requirements. HEART attempts to apply a simple structure to question authoring and OLL retains a tried and tested information structure. Also each step should be proven to follow the protocol so that it will represent a basis for the next step. Thus building strong foundations as progress is made.

In summary, through use of the design model, the development of future system will not be burdened by ineffective computer interfaces or shallow learning. The benefits associated with digital information can be gained whereas the drawbacks of interaction are not. Furthermore, the education value of the courses will not be lost and the teacher's involvement will remain high. Education is a social subject and computers have seldom been able to advance these subjects through advances in raw power. How that power is used to process information is how the computer can *aid* traditional education; but the computer alone cannot improve or replace well-authored courses.

Appendix A: Pre-Experiment Questionnaire

Here are a few questions intended to learn a bit about you before you take part in the experiment. Please use a circle to indicate your answers to the questions which follow.

1. Have you used Dr. Benest's Book Emulator before?

Yes **No**

2. When studying, do you prefer to have sample questions and their solutions from which to study?

Yes **No**

Please circle a number to indicate how closely you agree with the given answers.

3. When learning from a book, do you prefer to read it from the start to the end straight away or do you skim through the book to get an overview of it before settling down to read it?

Read immediately **1 2 3 4 5** Skim through first

4. When learning a procedure do you try to remember it by rote or do you learn the underlying mechanism for it?

Rote **1 2 3 4 5** Mechanism

5. Generally, how much do you enjoy the subject of digital electronics (IDD and DLD)?

A lot **1 2 3 4 5** A little

6. How well do you feel you know the coursework for IDD and DLD in order to participate in this experiment?

Very well **1 2 3 4 5** Not very well

7. In the main, do you prefer to work alone on examination style problems or do you prefer to work on them as part of a discussion group or team?

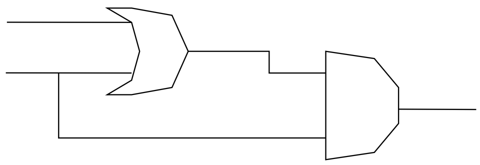
Alone **1 2 3 4 5** Group

Appendix B: Knowledge Test

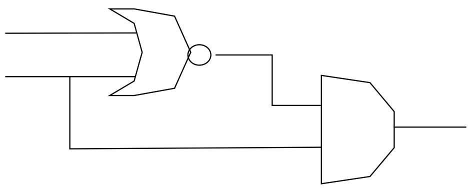
This knowledge test will indicate how much you know about hazards. Please clearly circle your answers to the following questions.

1. Which of the following digital circuits contain potential hazards?

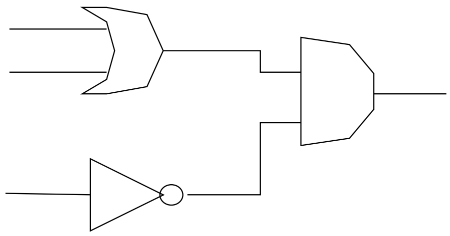
i)



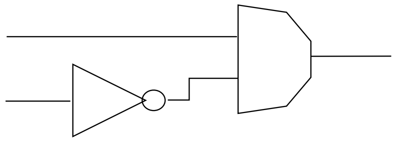
ii)



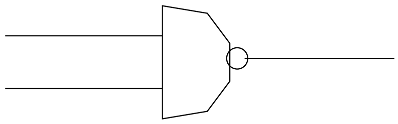
iii)



iv)



v)



2. Identify the essential prime implicants (E.P.I) and prime implicants (P.I.) on the following Karnaugh Map.

AB CD	**00**	**01**	**11**	**10**
00	1	1	0	1
01	0	0	0	1
11	0	0	0	1
10	1	1	0	1

Tick boxes in the following table to indicate which are essential prime implicants (E.P.I), prime implicants (P.I) or neither.

	E.P.I.	P.I.	Neither
i) $\bar{A}.\bar{D}$			
ii) $A.\bar{B}$			
iii) $\bar{B}.\bar{D}$			
iv) $A + D$			
v) $\bar{B} + \bar{D}$			

3. Which one of the following statements is true?

i) A dynamic hazard is a single momentary transient in an output signal that should have remained static in response to an input change.

ii) A static hazard is a single momentary transient in an output signal that should have remained static in response to an input change.

iii) A static hazard is a multiple momentary transient in an output signal that should have changed only once in response to an input change.

iv) A static hazard occurs when the input condition changes from maxterm to minterm.

v) A dynamic hazard occurs when the input condition changes from minterm to minterm.

Appendix C: Post-Experiment Questionnaire

In the following questions "HEART" refers to the exercise book, fragments book and clue book. The on-line lecture system used for reference material is not being questioned. Furthermore, the user-interface and technical presentation of HEART are not being questioned.

1. How quickly did you learn that placing the right fragments to each question would satisfy the system?

   Immediately **1 2 3 4 5** Not at all

2. When browsing the fragments, how easy was it to find the right fragments for each question?

   Easy **1 2 3 4 5** Difficult

3. How helpful were the clues for identifying the right fragments?

   Very **1 2 3 4 5** Not at all

4. Was it easy or difficult to understand the descriptions within each fragment and/or clue?

   Easy **1 2 3 4 5** Difficult

5. Did you ever disagree with the descriptions given in the right fragments to a question?

   Always **1 2 3 4 5** Never

6. By how much did the black and white pegs make it simple for identifying the right fragments?

A lot **1 2 3 4 5** Not at all

7. Did HEART help you to think (as opposed to **read**) through a solution to a question any more than usual?

A lot more **1 2 3 4 5** No more

9. Do you think that your understanding of hazards has **increased** directly due to the use of the HEART system?

A lot **1 2 3 4 5** Not at all

Open Questions

Ignoring the on-line lecturing system which was used to provide reference material, please make any suggestions in the spaces below:

1. My suggestions for improvements to the exercise, fragments and clue books.

2. Would you like to see the technique integrated into normal coursework.

3. Do you think this method of learning might affect the way in which you tackle examination questions and problems in the future, and why.

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