final study is presented in an attempt to provide an integrated answer to the question approached in the aim. The first stage in this process was the elucidation of a story line as described previously. It was then possible to examine the results presented in this chapter in terms of the aim of the study.

Chapter 9

A study into the use of a student model in a multimedia application: Discussion

9.1 Introduction

In the previous three chapters, the design, implementation and evaluation of an individually configurable multimedia learning application, Application of Number, was described. In this chapter, the results of the evaluation are discussed in terms of the aims of the investigation.

The research question posed in the final study was in what ways a multimedia application configured for an individual learner, using a co-operative adaptive student model approach, was beneficial in the delivery of effective learning. The approach adopted in answering this question was based on Grounded Theory. The stages in the Grounded Theory method employed in the study were described in chapter 7. They included an initial phase of open coding, where the issues involved in the complex research question, or phenomenon, were identified. In the axial coding stage, important categories in the phenomenon were related to their sub-categories and dimensions of each category were identified. The results of the open and axial coding stages are shown in Appendix 15. In the selective coding stage of the project, a story was developed. The story was a descriptive narrative about the central phenomenon and involved the identification of a core category, the story line. The theory is grounded by identifying the core category and relating other important categories to it causally and validating those relationships with data (Strauss and Corbin 1991).

In this chapter, the core category and related categories are described and a descriptive narrative relating to the phenomenon is presented. Causal relationships between the categories were identified and are presented, using data from the evaluations performed and described in the previous chapters.

9.2 The core category

In order to understand the complex interactions observed in the use of the Application of Number multimedia application, it became clear that a far wider set of issues than the application itself needed to be understood. These issues were first identified in the open and axial coding stages of the research and were further refined in the process of selective coding. As the project progressed it emerged that an evaluation of the application necessarily involved a consideration of a larger context than learners and their use of the application. The following is a summary of issues, important in this larger context, presented in the form of a narrative. This was intended to lay the foundations for the identification of the core category, the central phenomenon around which the research question was based, presented in section 9.2.1.

Early in the study, during the preliminary open and axial coding stages, it became clear that the three main stakeholders concerned with the application were students, tutors and the learning or educational system. The evidence for this came from questionnaires and interviews with staff, reported in sections 7.3.1 and 7.3.2, where they were consistently identified as being central to learning with multimedia. Student was seen as the direct beneficiary of the learning process, obtaining learning, skills and qualifications from using the application. Their investment was in the time and effort necessary in order to use the system effectively and the course fees to undertake the course. The role of the tutor was to guide, manage and facilitate learning. Tutors were required to work alongside learners, configure and adapt the student model for each learner, set and monitor targets, to act as an expert and to ensure that the systems were used properly. It was found that there were several important outcomes for the tutor. These included issues related to successful management of the course, pass rates, retention rates and also issues related to their professional practice, such as staff development in new educational methods.

The learning/educational system, the third main stakeholder, was defined in a wider sense as the academic and related institutions that set up and managed the courses that learners undertook in order to obtain qualifications. An important function of the learning system was their investment in the infrastructure required in order to run courses. It was clear from the outset that the educational system had significant external influences, such as funding bodies, awarding bodies, staff and student organisations, government and inspection bodies. Important outcomes for the learning system included cheaper and more efficient learning, marketing and publicity, better student recruitment, retention and better results.

A complete evaluation of the learning process had to be viewed in respect of the interactions between all the stakeholders. In terms of the multimedia application, the most important interactions in the context of the final study were those that directly involved students and tutors. However the learning environment was important as the stage for these interactions. The local environment where learning took place, the microenvironment, was in part the product of students and tutors and their use of the learning application. But it also included the hardware and software required to follow the course and the physical quality of learning resources and areas, such as classrooms, computer rooms, libraries and learning centres. The microenvironment included influences from the institution macroenvironment. The macroenvironment provided a wide range of support required in order to establish a working microenvironment within which courses could be followed. This support ranged from technical support for computer systems, learning support for students, the provision of open access study areas to the provision of training for staff in the use of new educational technology.

It has been argued that learning is situated in a social, vocational and academic context and so its evaluation must be similarly situated (Squires and McDougall 1996; Squires 1997). The use of the learning materials in this study took place in a context which, it is argued, had a significant influence on how they were used, how they were evaluated and the outcomes that resulted from their use. It is argued that by using them in the six locations in the final study, differences might be identified and causal relationships be identified where this was possible. It was not the intention to average out differences between locations, or to control for them, but rather to identify and consider any effects that they might have on the process.

The research question then was concerned with how the quality of a multimedia learning application as perceived by the stakeholders was affected by individual configuration according to a model of learners. An important related issue was how the stakeholders themselves were influencing the quality of the learning taking place, due to their input into the system.

The Grounded Theory approach employed in the final study was important in unraveling the complexity of the phenomenon as set out above, rather than trying to control it. The contribution made by the research methodology will be discussed in the next chapter.

9.2.1 The quality of learning

The quality of learning was identified as the core category or the central issue in the study around which the research question could be understood. It is clear from the previous discussion that the quality of learning was influenced by many factors both internal and external to the direct learning experience provided by the use of the application. The research question has therefore been refined in order to understand how these influences affected the quality of learning.

The quality of learning itself was found to be a complex issue which was related to many uncontrollable factors. In order to understand the complexities of these relationships, several categories that were closely related to the central phenomenon were identified. Three main categories that were central to the research question were:

- The student model
- The learning materials
- The management of learning

Many sub-categories and factors related to the main categories were classified in the preliminary stages of the study and are shown in Appendix 15. Table 9.1 below, summarises the main categories and sub-categories identified.

The relationships identified between categories and sub-categories presented in Appendix 15, were in many respects arbitrary. The validity of the relationships presented here were determined to a large extent by their usefulness in understanding the phenomenon. The following shows the relationship identified in this study between the main categories and sub-categories. These were identified as being closely related to the central phenomenon, the quality of learning and were seen to be consistently related at all stages of the study.

Table 9.1

A summary of the relationship between main categories, sub-categories and important factors relating to the quality of learning

(See also Appendix 15)

Main Category	**Sub category**	**Factors**
The student model	Performance – results	Pre-test Post-test On/Off computer tests On/Off computer tasks
	Components of the student model	Language Cognitive style Task level Question level Scaffolding
	The co-operative student model	Configuring the variables
The learning materials	Subject content	Level Performance criteria Evidence Accuracy
	Design features	Quality Screen design
	Usability	Robustness Ease of use
	Learning presentation strategy	Collaborative working Context Differentiation for the individual The use of questions The use of scaffolding The use of tasks
The management of learning	The tutor	Involvement
	The learning environment	The microenvironment The macroenvironment

In order to produce a rich understanding of the phenomenon, causal relationships between the main categories, sub-categories and factors displayed in table 9.1 were obtained. Evidence for these relationships was gained from the experiments, observations, questionnaires, reports and interviews presented in the previous chapters. A great deal of evidence for causal relationships between the main categories and sub-categories was also obtained from open and axial coding stages of the research presented in chapter 7 and from earlier experimental work and exploratory studies presented in chapters 3, 4 and 5.

In the rest of this chapter, evidence for causal relationships between the categories and sub-categories described above is presented.

9.3 The student model

In this section, the usefulness of the student model approach in the configuration of learning for an individual learner is discussed in the light of the evidence obtained. The way in which the student model impacted on the quality of learning is also described. The reason for using a student model approach centred around the notion that by considering each learner as an individual and configuring learning based on a knowledge of that individual, the learning experience provided, would be beneficial to the quality of the individual's learning process.

The student model developed in the study was a simple model of learner characteristics, which included language, cognitive style, task and question level and help level. In previous work described in chapters 4 and 5, it was shown that the individual configuration of multimedia learning materials for language and cognitive style was beneficial to some learners. In the first experiment, it was found that learners with poor language skills performed better on a multimedia food studies course when additional language support was provided, though the provision of additional support did not benefit those learners whose language skills were good. In another investigation it was shown that learners at the extremes of Riding's Verbaliser/Imager dimension (Riding 1991b), performed better in sections of a multimedia communications application when the presentation mode was configured to match their preferred cognitive style than in sections where it was not.

These results strongly support the efficacy of using language and cognitive style as the characteristics of a learner within a student model. In the final study, the student model held information related to the presentation of tasks, questions and scaffolding in addition to language and cognitive style. Evidence for the effectiveness of differentiation of the multimedia material based upon these factors was obtained in exploratory studies described in chapter 3. Four multimedia courses were developed in the exploratory studies to test the effectiveness of these ideas. In the exploratory studies, applications were developed based upon the use of differentiated tasks and questions, rather than the more traditional multimedia courses that delivered large amounts of information or instruction. Applications provided different routes through the course for individual learners, depending on tasks and question level being followed. The results of the exploratory studies suggested that there were benefits to tutors and learners due to the approach of differentiating scaffolding, tasks and questions.

9.3.1 Performance – results

It was considered inappropriate to base the evaluation of the Application of Number prototype on a direct comparison of learners' performance scores between the users of the multimedia system and comparable alternative systems, for example lectures. The requirement to provide an individually configurable environment for each learner in itself made it impossible to ascribe differences in results obtained on the multimedia course to any specific cause. It would have been possible, for example, to ascribe differences in performance to language level configuration, or task level, or indeed to differences in the in-course questions themselves. Differences in results could be due to any number of differences in the configuration of the student model for the learner. An individual learning experience therefore required an individual evaluation approach that would be rich enough to allow for the complexity of the phenomenon.

The results obtained in tests on a course however, are an important outcome for learners. It was important to be able to show that on average, learners performed as well or better on the multimedia course as they would on alternative courses. An additional reason for including performance as an important factor in evaluating the multimedia course is that learners are well-motivated when they perform at a high level and tutors are more likely to invest their time and effort into using the application in this case.

One indication of evidence for performance on the course was provided by the results of pre-test and post-tests. In particular, comparison with the results from a non-multimedia mirror course taking place at the same locations suggested that the student model approach provided several benefits for learners. In the previous chapter, a statistical analysis of the pre-test and post-test results was presented. The results of these tests shown in table 8.3, indicate that the mean post-test scores were better in multimedia groups than in non-multimedia groups ($p<0.01$). The pre-test results showed no difference between conditions ($p>0.05$). These results were taken to indicate that the multimedia application was capable of delivering the required skills for the course at least as well as or better than a non-multimedia mirror course, as measured by performance on a post-test. This, it is argued contributed to the quality of learning provided by the application.

This result is important because performance is an important outcome in learning, not only for learners, but also for the other stakeholders involved, the tutors and managers of learning. In the open and axial coding preliminary stage of the study, described in section 7.3, performance was rated as an important measure of the quality of learning by all groups surveyed.

There was also important evidence relating to performance from inline tests taken within the application. Examination of table 8.7 shows that learners performed at a high and consistent level irrespective of the level of task or question set for them, scoring above 75% on all questions and tasks. This was an important result, since these tests were used to assess the understanding of topics covered in the application and also to reinforce learning taking place. In-line questions and tasks were used not only to provide a measure of performance on the course, but also to measure how well students understood concepts covered by the course and how well they were able to translate that understanding into the performance of tasks. As suggested above, it was also important that learners obtained motivation by the feedback provided by their performance.

It was a major achievement of differentiation provided by the student model that learners were performing equally well at all levels One important goal of differentiation was to present information at the most appropriate level for each individual learner. That this was achieved is indicated by the scores obtained. More able learners were challenged by questions and tasks and those requiring most support in their learning were able to achieve course objectives, though at less demanding cognitive levels. It is argued that the quality of the learning provided was enhanced at all levels by this approach.

The possibility of configuring tasks and questions in this way had an important and interesting influence on the tutor, as will be discussed in the following section. Several tutors remarked in reports and interviews that this was an important feature of the application. Others considered that it was a negative feature of the application and tended to reward less able students with higher marks. Certainly there was a great deal of evidence that learners perceived the course to be relatively easy. This may have related to the configuration of task and question level. However, it is argued that the ease of following a course is likely to be related to the quality of the whole learning experience provided, not only to the difficulty of tasks and questions.

There were three main areas of concern identified by tutors, related to this feature of the application: the need for tutors to obtain and exercise new skills; and the need for some tutors to adopt a different philosophy relating to the use of questions and tasks; and concern over the time necessary for tutors to use this feature to its best effect. These issues will be considered when configuring the student model is discussed later.

In the next section, the individual components of the student model are discussed and their influence on the quality of learning is considered.

9.3.2 Components of the student model

The student model employed in the study was a simple model of learners' characteristics. Ohlsson (1993) refers to this approach to student modelling as the 'global description of the learner'. Milne and colleagues (1997; 1996) refer to this type of model as a 'model of user attributes'. Ohlsson's global descriptors are composed of variables which describe the characteristics of a learner. The global descriptors used in this study and their influence on the quality of learning are described below.

9.3.2.1 Language

The requirement to allow for different language ability in learners has been made by several authors (Barron and Atkins 1994; Molich and Nielsen 1990; Kenworthy 1993). The results of the experiment described in chapter 4 suggested that the major influence of language differentiation would be on learners with poor language skills. There was evidence from the questionnaire data presented in table 8.6 that learners considered the language to be pitched at the right level (41%). Only 6% considered the language used to be very difficult and 25% considered the language used was too simple. It appears therefore that learners with poor language skills were presented with an application that supported their deficiencies. In future courses it would however be important to identify the group of learners who reported that the language used was too simple, and provide additional challenges for them to make certain that they were working at their most appropriate level. Language levels were not adapted as learners progressed through the course, though the facility to adapt language level was provided. It would be an important feature of future work to investigate the effect of adapting language level. It was shown in chapter 4 that the diagnostic test used to assign the value of the language descriptor was effective at identifying those learners who required additional help. The results of the final study suggest that additional testing and perhaps on-line adaptation would be beneficial to learners with higher-level skills.

The instructional design review completed within the expert review of the application described in section 8.2.11 rated the appropriateness of the language used to be high. Learners stated in interviews that they felt that the language used in the application was at the correct level. In the interviews, learners provided a picture of a learning experience that was not linguistically challenging, irrespective of their individual level. It is therefore argued that the intention to deliver the domain content at the most appropriate language level was by and large achieved, and that this contributed to the quality of the learning provided.

The direct influence of language level on performance was difficult to measure however. Data logging evidence (see table 8.5) was able to show that there was only a small difference in performance on in-line questions between six learners configured at the lower level (i.e. provided with additional support) and three learners configured at the higher level. These results are taken to indicate that learners performed at a high level in the domain, irrespective of the language support provided for them individually.

The use of sound in the application was closely related to language ability. Sound was reported in staff reports by five tutors as being important for learners with poor language skills. This additional language support was available to all learners. However, it was not perceived, as beneficial to the learning experience by all learners. There was evidence from data logging that those learners with higher language skills who required less support were more likely to configure sound off or interruptible, allowing the presentations to proceed at their own faster pace. Questionnaire data supports the view that whilst the majority of learners perceived sound to be an important feature of the application, 29% thought it not to be useful. Taken with the data logging evidence it is likely that the benefits of sound were more important to those with a need for additional language support than for those with good reading and listening skills. Evidence from focus group discussions largely supported this view. Sound had the effect of slowing down some areas of the application which was reported as being a poor feature by some learners. Sound was disabled by some users who said they could read faster than the sound was being presented and sometimes this was reported as being confusing. Other users reported that the use of sound in the application was useful in supporting their reading and listening. The ability to hear spoken explanations of complicated animations was also cited as important by some learners.

9.3.2.2 Cognitive style

The use of cognitive style as a descriptor in the student model was important for several reasons. The importance of allowing for individual learning and cognitive style has been recommended widely (Entwistle 1981; Riding and Watts 1997; Kolb and Fry 1975). The design of interactive individually differentiated learning materials presented an ideal opportunity to implement the configuration of learning according to cognitive style. Cognitive style had also been shown to influence performance in previous work. The results of an earlier experiment described in chapter 5 suggested that the major influence of cognitive style differentiation on performance in the application would be on learners at the extremes of Riding's Verbaliser/Imager scale. It was also considered important that learners were given the most appropriate mixture of text and images to increase motivation, enjoyment and satisfaction with the application and learning experience provided.

It was difficult to isolate the effect of cognitive style on the quality of learning. Direct evidence for the effect of cognitive style differentiation on performance was difficult to separate from the many other factors having an influence. The experiment described earlier suggested that any effects observed in the study were likely to be subtle and would be swamped by the effects of task, question and language differentiation. Data logging evidence from a small sample (n=9) showed that on average Verbalisers performed better than Imagers on the course (table 8.5). This could be related to the shorter time spent by Imagers per presentation screen (23 seconds). Bi-modal learners spent nearly twice as long per screen (45 seconds). Time spent answering questions was approximately the same for Verbalisers, Bi-modals and Imagers.

Indirect evidence for the effect of cognitive style on the quality of learning was provided by the focus group sessions where learners thought that the mix of text and images provided was satisfactory on the whole. This was despite learners having considerably different presentations depending on the value of the cognitive style descriptor set for them. Tutors reported that some learners preferred a Bi-modal presentation of text and images and they were able to change presentations to this configuration in a small number of cases. The verbal narrative that accompanied text was reported as being useful to many learners. More narrative was provided for Verbalisers than for Imagers, as it was based on the text presented. It was clear from a great deal of evidence that the learning experience was positive for learners and that the balance of text, narrative and image was considered appropriate for Imagers, Verbalisers and Bi-modal learners. Nowhere did learners or tutors consider that the course was presented in anything but an appropriate mix of words and pictures.

It was also important to consider the effect of the cognitive style descriptor on the tutors' attitude to the application. Tutors reported that they valued this aspect of the student model and were able to see the overall importance of the approach. There was evidence that tutors valued the ability to differentiate the application according to cognitive style. This in itself was a positive aspect of the application according to staff interviews. Somewhat paradoxically, in staff reports, cognitive style was cited by tutors as being the least important variable in three reports and as the most useful in one other. When drawn on the reasons for this, two tutors who cited it as being least useful stated that they considered it to have an indirect or small influence on performance in the application, when compared to the effect of other descriptors, but probably had a greater influence on student motivation. These tutors rated other descriptors in the student model as having a larger effect on performance than cognitive style. Indeed, in their reports four staff recommended the addition of further cognitive styles in future developments of the student model, suggesting that this was considered to be a useful descriptor in a student model.

The effect of cognitive style on learning then was perceived more as influencing attitude to learning rather than having any large direct influence on performance. In staff interviews, the importance of cognitive style on attitude was emphasised by several tutors who considered that cognitive style differentiation contributed to the overall perception of the quality of the learning application. Cognitive style, learning style and learning strategy were consistently rated as being important features of individually configured multimedia in the preliminary open and axial coding stages of the study, as described in chapter 7. To summarise, the use of cognitive style as a variable in the student model ensured that the majority of learners were presented with a presentation configured appropriately, containing a good mix of text and images. Staff motivation and attitude to the application was influenced positively by the use of this descriptor in the student model.

9.3.2.3 Task level

An important feature of the Application of Number application was the task-based approach to teaching and learning. Tasks were shown to be important in the exploratory studies where applications were developed that were centred around the use of tasks and questions, rather than the more traditional multimedia courses that delivered large amounts of information. Tasks were shown to be important in a constructivist view of learning (Grabinger et al 1997; Park and Hannafin 1993) and provided a means of engaging students' attention.

The use of tasks was intended to support the development of higher-level cognitive skills, to support reasoning skills at the appropriate level and to provide opportunity for the application of new skills at higher levels. In this way, it is argued, tasks were used to improve the quality of the learning provided in the application. Tasks were configured within the application at three levels, either implemented as either on-computer or off-computer activities. At the lower levels, tasks could be solved easily by learners, providing motivation and a guided and supported environment within which to experiment with the application of new knowledge. At higher task levels, there was a greater cognitive demand placed on learners, often requiring the application of a new skills in a specific context. The pedagogical opportunities provided by task-based learning will be discussed later. In this section, the influence of the student model configured for differential task levels is discussed.

Evidence from interviews with learners (see table 8.2) suggest that they found the tasks to be better compared to those provided on other courses. In the interviews, 22 out of 24 learners reported that tasks were easier or the same as other courses and 20 out of 24 learners reported that the quality of tasks was high in this course. This is supported by the questionnaire data (see table 8.6) where only 22% of learners reported that they found the tasks to be difficult. Given that learners were working at three different task levels, these results support the view that differentiation of task levels was able to provide an appropriate task-based environment for learners. The fact that some learners reported in questionnaires that they considered the tasks to be relatively difficult suggested that these learners were being challenged by the tasks. The perception of quality was high, even in those learners who perceived the tasks to be challenging at their level.

Evidence from data logging (see table 8.5c) was interesting, despite the small sample size. The time spent per task screen for on-computer tasks was directly related to the task level at which they were set, learners invested greater time in the higher-level tasks. The mean score per task did not appear to be related to the task level however. Learners at higher task levels were investing more time for no gain in score. However it is noted that the function of tasks in learning is not just related to achievement. The amount of time invested in performing a task can be seen as a measure of a learner's engagement rather than the score obtained for completing the task.

Experts considered the application to be task-based, rating it at on average 4.25 out of a possible 5 (see table 8.10). The screen activities were considered to be well-planned (3.75) and on-line questions and tasks were rated as good (3.5). It was difficult for expert raters to have an overview of any specific aspect of an individually configured and differentiated application. Even after using the application at several levels, experts reported this difficulty. However, there was good general agreement between experts on most topics reviewed.

9.3.2.4 Question level

The inclusion of question level in the Application of Number course was based on similar considerations to the use of task-level differentiation. The use of questions is important in developing good approaches to learning (Felder and Brent 1994). Questions in the course ranged from simple multiple choice selections testing recall of simple information, to tests of the organisation and structuring of quite complex ideas. The pedagogical issues related to the use of differentiated question levels are discussed later. In this section, evidence for the influence of the question descriptor on the quality of learning is discussed.

It is argued from the results presented in tables 8.5c and 8.5d, that configuring questions at appropriate levels led to improved test and task results for some learners. Learners configured at low levels of the question descriptor performed equally well or better on average, in tasks and questions, than learners configured at higher levels. In-line assessment was rated equally good or better than other courses followed by learners and the quality of questions in the course was rated highly in interviews with learners (see table 8.2). Tutors in interviews were in agreement that improved performance on in-line assessments was due to configuring the question level to the level of each learner. There was some concern over lowering standards on the course due to this factor. This concern will be discussed later.

Understanding the need for configuration of tasks and questions and the requirement for tutor involvement in configuring the applications was a major outcome of the study and is discussed later.

9.3.2.5 Scaffolding

Scaffolding is the support and help provided for learners, which may be removed when no longer required. The provision of a range of supported environments has been described by several authors (Bloom et al 1997; Stoney and Wild 1998; Calvani et al 1997). Scaffolding can also be used to help extend a learner's knowledge (Somekh 1996). Scaffolding in these cases is used to assist learners to pass their current level of achievement and enter their zone of proximal development (Vygotsky 1986). Within the Application of Number course a differentiated and configurable help system was provided that was intended to help learners extend and develop their skills.

The type of scaffolding provided within the application was largely based on supporting the tasks that learners had to undertake. The system of scaffolding employed in the Application of Number course was developed in the exploratory studies described in chapter 3. The principle of the system employed was to provide help in the context of the task being undertaken, at a level appropriate to an individual learner. As learners progressed through the tasks, optional additional help was made available as needed. The level and sequence of this help was configurable at three levels by the tutor in cooperation with individual students. This differs from other approaches where help is presented sequentially, irrespective of learners' prior skills or requirements. Learners with high-level skills could take responsibility for deciding what help they required. Some learners benefited from hints and strongly linked suggestions. Other learners required a fully configured help system directly linked to the tasks being undertaken.

Data log files (table 8.5) showed that the time spent accessing help was greater for learners configured at the lower levels of the descriptor (i.e. provided with more help). Time spent per screen was more and also there was more help screen accesses with these students. Students working at higher levels of the descriptor were provided with less help by default, though it was available if required. These learners used the help less and spent less time per help screen than other learners. This supports the view that learners were provided with an appropriate level of help for their individual needs within the application and did not need to access deeper levels of support. Learners were aware of the scaffolding provided and were able to use it if required.

The help system was generally considered to be a positive feature of the application, enhancing its quality. In the student interviews, 16 interviewees considered the help system as being good and simple to use, which was largely supported by the questionnaire data. The philosophy used in the design of the scaffolding and help system was valued by tutors and mentioned as being a positive feature of the application in reports and in staff interviews. The help system provided was rated by experts as good and provided at the correct level (table 8.10), achieving an average score of 4.5 out of a possible 5. The pedagogical implications of the use of scaffolding in the Application of Number course are discussed later.

There was evidence that even with help differentiation, learners were using the scaffolding differently. In interviews some learners reported a more browser like approach to navigation and using the help systems. Others used the help system in a more or less linear fashion as and when necessary. There was also some evidence from user log files that different approaches to navigation were employed especially where help and scaffolding were used. This is an interesting feature of the ways that different individuals used the scaffolding feature which would be important to consider in future work. It is likely that this different use is related to different learning strategies and it might be possible to support these differential styles for the individual. Issues related to the configuration of help levels for individuals is discussed in the next section.

9.3.3 The co-operative student model

Learners bring a wide range of prior knowledge, skills and individual characteristics to the learning situation. It was considered an important requirement that the learning experience provided by the application be tailored for each individual, taking into account individual differences in learners. It was envisaged that this approach would contribute to a high quality learning experience. Treating each learner as an individual was intended to provide a unique learning experience for every participant in the study. Learning was individualised in a variety of ways, by the flexible way in which the course could be followed by learners, by having learners work in groups in off-computer activities, by working with tutors in setting and monitoring individual targets and also by the task-based approach employed which allowed learners to contribute in their own way to the activities provided. In addition to these features, it is argued that the most important way in which the use of the on-computer activities was individualised was by the use of a co-operative adaptive student model.

The skills and characteristics that learners brought with them included prior knowledge and skills within the domain. The characteristics of learners were also important however, for example, language skills and cognitive style had already been identified in previous experimental studies as influencing performance on multimedia learning applications and hence influencing quality. Many other factors capable of influencing learning performance and the learning experience have been identified, such as intelligence and motivation. Entwistle (1988) for example, identified a range of factors related to an individual that were shown to influence learning. Individual configuration using a student model based upon learners' individual characteristics was important as the best way to configure the presentation of the learning application for individual learners as they followed the course. It was also important that a co-operative approach was adopted to setting and adapting the configuration of the student model for each individual.

A co-operative student model is a model of a learner that is configured in co-operation between humans and computers. The use of such models in learning applications was described earlier in chapter 6 of this work. An important requirement of the Application of Number course was that it took into account all the main stakeholders in the learning process, including tutors. The reason for this approach was that there was a great deal of evidence from exploratory studies, and later from the preliminary stages of the project, that the use of educational technology was often seen to exclude or replace the role of a tutor.

This was largely perceived to be a negative aspect of the learning process by tutors who considered that they had lost control of the process. There was evidence that this led to a poor quality learning environment that benefited none of the stakeholders. It was argued that by involving tutors and students fully in the learning process in the Application of Number course, this problem was largely removed, causing a far greater positive attitude to the materials by tutors, greater motivation for all stakeholders and a higher quality learning experience. An important way in which each tutor was involved in the Application of Number course was the requirement that they establish and adapt some of the descriptors used in the student model, in co-operation with individual learners. The evidence for the effectiveness of this approach is presented below.

9.3.3.1 Configuration of the variables

The requirement that tutors and learners work together to establish between them the best way in which to follow the course was seen as important, not only by tutors involved in the course, but also by the course designers and by a wide range of tutors and managers in FE. The evidence for this came initially from the early stages of the study, during open and axial coding. It was not surprising therefore that in the study itself, the co-operative approach was seen as important in the quality of the learning materials for individual learners. Tutors reported in interviews, focus groups and in their diaries that the co-operative method of configuring the student model was considered to be an important feature leading to high learning quality. There was also some anecdotal evidence for this from staff training sessions, where sessions were often fairly negative about the approach at the beginning of the session, but became more and more positive as tutors realised exactly what was involved in using a co-operative student model to configure learning. This raises important issues for the use and evaluation of multimedia learning materials which will be discussed in the next chapter.

The use of a co-operative student model allowed some *human* flexibility to be incorporated within the application. It was reported by tutors and learners that there were many occasions where students completed a section at a low level of task or question and repeated the section later at a higher level after negotiating new targets with their tutor. This sometimes occurred without establishing a new setting for the task or question global descriptor, with learners returning to the relative security of their previous level after completing a higher level activity.

There was evidence from the study that learners valued the co-operative approach to learning with multimedia. When learners encountered difficulties in the course, the co-operative nature of the student model ensured that changes in level took place regularly as required. Progress was continually monitored and students could report when things needed to be changed. A summary of changes in the settings of task, question and scaffolding levels is presented in table 8.8. Early in the study, learners were mostly adjusted from higher to lower levels of tasks and questions. Once the correct level had been set, subsequent movements were almost always to higher levels. This is an important result that shows that learners were gaining confidence as they followed the course and were ready to accept additional challenges. It is sometimes argued that similar results could be obtained from purely automatic re-configuration of levels based upon performance in the domain. Indeed such systems have been reported (Woolf and Murray 1992). However, it is argued here, that the best measures of learners' confidence is the learners themselves and that learners' confidence may involve many factors outside of the domain. In this study tutors and learners were able to negotiate changes based not only on scores in tests and performance on tasks, but also in a fuller context that involved learners' perceptions, attitudes, examples, implications and judgements. Changing from a lower to a higher level is a risk for learners (and also their tutors) that involves balancing rewards against returns. This process in itself it is argued, was valuable for learners as a means of introducing an overview of learning and asking them to place their own learning into a wider context. Moving to a higher level was a source of extrinsic motivation for learners, which led them to a higher quality experience.

Tutors commented in interviews and reports that they were confident that students were able to follow the course at their own appropriate level. The main problem reported with the approach was the additional time required for meetings in order to monitor progress. Learners were responsible for collecting, collating and presenting their own evidence of progress on the course. For several reasons this was not always done. Some tutors preferred to collect marks and task scores themselves from the application, using the rather limited tools provided. Some learners were not successful in collecting evidence, which wasted tutors' time. These points are returned to when the management of learning is considered later.

There was considerable evidence that the co-operative approach employed in the study caused a change in tutors' attitude to the application and student modelling in particular. Some tutors involved in the study reported that they had previous experience with Intelligent Learning Systems (ILS). In such systems learning is controlled automatically, based upon learners' performance within the domain (Angelides 1995). In the initial study undertaken during open coding, the student model/artificial intelligence approach was rated quite low on the importance scale by a wide range of workers in FE. The components of the student model used in the study however were rated far higher by the same workers. Language, cognitive/learning style and the use of scaffolding/help systems were considered by most workers in the FE area to be important in learning with new technology. The need for a task-based approach, differentiation and appropriate use of questions were also rated as important. This was an important result, since the use of AI methods was rated lowly, yet the components of the student model used in the study were rated highly as important features in a multimedia application.

In interviews all tutors involved in the study were asked if there had been any change in their attitude to the use of student modelling over the course of the study. All tutors reported a positive change in attitude. However, the greatest positive changes were found in those tutors who reported previous experience of ILSs. One tutor initially rated the student modelling approach as 'a very poor strategy', or as another tutor put it, 'unnecessary'. Yet after experience with the co-operative approach used in the study, tutors changed their opinions positively. This evidence suggests that although the components of a student model may be considered to be important, tutors may have a negative attitude to its use in learning, as experience with automatically configured systems can lead to dissatisfaction with student modelling. Only after some experience with co-operative student modelling was a positive change in attitude seen. The implications of these results will be discussed further in the management of learning section later.

In conclusion, the co-operative approach was rated highly by tutors and students in the study and was the major cause of positive changes in attitude of tutors to the use of student models.

9.3.4 Summary: student modelling

There was evidence from the investigation that by using a student model, learning could be configured optimally for individual learners. The benefit of this approach was considered to be important for both learners and tutors and to influence the quality of learning. The student model employed in this study was a simple model of learners' characteristics. Ohlsson (1993) refers to this approach to student modelling as the 'global description of the learner'. Ohlsson's problem with the global descriptor approach is summarised by his question, 'how are these descriptors to be used to individualise instruction?' There are few 'micro decisions' which depend on the value of such descriptors Ohlsson (1993). Global descriptors lack 'pedagogical power' because they ignore the content of the knowledge being taught. Ohlsson's solution is the application of 'overlay models' which individualise the presentation of learning according to models of learners' knowledge states.

Ohlsson's view of the use of global descriptors may be based on an instructionalist view of learning. Ohlsson's requirement for micro decisions within the application to configure the presentation of learning is similar to the ideas inherent in programmed instruction based upon Skinnerian ideas where performance in the domain was used to control the presentation of information (Patrick 1992). The results of this study suggest that the most important and richest micro decisions should be made by learners in consultation with tutors. A student model based upon a model of the learners' characteristics has the potential to improve the quality of learning by optimising presentation for each individual. Learning decisions are under the control of individual learners. The constructivist view of learning implies that presentation of information is only a part of the learning process. The way in which a learner interacts with the information and others is also important.

The constructivist view of learning around which the application was developed overcomes Ohlsson's objection. The key element of a knowledge-based approach is to keep separate the difference between strategies and domain knowledge (McIntyre 1993). Ohlsson's overlay model is a model of a learner's domain knowledge state which is used to determine the strategy as to the how information is to be presented to that learner. However, Cummings (1993) states that learning must always be the primary focus in intelligent systems, and challenges the view that learning can be presented effectively to a learner as Ohlsson suggests. It is argued that the co-operative approach used in this investigation is able to provide a high-quality individual learning experience, configured according to important global descriptors of each learner. These were useful in presenting challenges and information at an appropriate level for a learner. The important micro decisions that determined how learning was to take place were under a student's control, under the tutor's guidance. In this way learners were free to use the richness of the application environment to construct learning for themselves.

In the next section, the influence on learning of the multimedia materials themselves is discussed.

9.4 Multimedia materials

It is a widely held belief that the use of multimedia learning materials *per se* is of great benefit to learners. The reasons for this belief range from the great intrinsic motivation provided by high-quality learning materials and the use of media to present information in an interesting and useful manner (Tannenbaum 1998). The use of multimedia it is argued does not always lead to a high-quality learning experience. The pedagogical assumption that a multimedia learning environment always produces high-quality learning has been challenged by Tergan (1997). Tergan states that there is little empirical evidence to support this view.

In order to ensure that maximum benefit was gained from the rich multimedia environment, the multimedia materials specified for this study were required to be usable, have high-quality design features and importantly, to be based upon sound pedagogical features. In the next section, evidence for the effect on the quality of learning, of the subject content, usability, design and pedagogical features included in the multimedia application is presented.

9.4.1 Subject content

The subject content of the materials was an important feature that influenced the quality of the application. It was clear from exploratory studies and from the open and axial coding stages of the project that subject content was important if materials were to be used effectively by tutors and students in courses. The effective use of multimedia materials is an important factor in the quality of learning.

There were special features of the Application of Number course that influenced the way that the subject content was approached in the application. The multimedia course was based upon the General National Vocational Qualification Application of Number course. GNVQ units are composed of a set of elements that represent themes within the course. For example, the elements of the GNVQ Application of Number course were, Collect data, Use data and Present data. Each element has an associated set of Performance Criteria specifying skills that must be satisfied in order to pass the element. For example two Performance Criteria in the Collect data element were: Collect data from a written source and Collect data from a non-written source. Performance Criteria are specified by the awarding body and are associated with a range of skills that must be covered to satisfy a Performance Criteria. GNVQ students are required to provide evidence that they have satisfied the Performance Criteria to achieve an element. To do this, a range of necessary skills (specified by the awarding body) is covered by students who are responsible for presenting evidence to their tutors. The subject content of the course, then, was specified by the awarding body as the range of skills that were required to be obtained in order to satisfy the Performance Criteria in a unit.

The task-based approach adopted in the multimedia application was intended to assist students to use the tasks completed as evidence that they had satisfied the Performance Criteria and the range of skills in the course. It was important therefore that:

a) Tasks in the multimedia course could be related directly to units, elements and Performance Criteria and the range of skills to be covered in the GNVQ unit;

b) Tutors, internal verifiers and external moderators would accept completion of the tasks and assignments in the application as evidence that the relevant skills had been acquired;

c) Tools were provided to help students and staff in the management of this process.

The subject content of the application, then, was designed to provide evidence that students could present to tutors to show that the range of skills and the Performance Criteria had been covered. Tutors in turn had to be satisfied that the evidence provided was of the appropriate standard and then to present this to internal verifiers and external moderators. Thus it is noted that tutors were more concerned with the level and quality of evidence provided by the application than the subject content.

Interactive charts and diagrams were provided within the application as tools to help staff and students understand the relationship between units, elements, Performance Criteria, the range of skills and the tasks and assessments. This feature was important to all stakeholders. Managers could be sure that evidence presented covered all the necessary criteria to satisfy awarding bodies. Learners were aware of exactly what was required to obtain their qualification and tutors were involved in the process of monitoring the tasks completed by learners and assessing the evidence provided.

The subject content of multimedia learning materials had been a major concern of developers and stakeholders. This was evident from interviews and from the open and axial coding stages of the study. The content of other multimedia applications was frequently criticised by tutors in terms of its accuracy, relevance, level and was also seen as liable to change by awarding bodies or other factors and external events. The use of the task-based approach, rather than a content-driven approach overcame many of the problems. Tutors reported that the approach used was a major reason for change in attitude to the course over the duration of the study.

Students and tutors found the assessment-based approach to be an important feature of the quality of the Application of Number course. In this approach, content was geared entirely to assessment and evidence. Tutors could decide if the evidence was appropriate or not and negotiate with learners in the confidence that Performance Criteria were being covered by tasks and assignments. The movement from content-driven to task-driven application also supported a move from an instruction-based approach to a constructive learning approach. The importance of this approach to the management of learning, the underlying pedagogy and the quality of learning will be discussed later.

9.4.2 Design features

The positive effect of high quality materials on learning through multimedia has been advanced by several authors. The case for the incorporation of sound design theory into the application has been made by many authors. McAteer and Shaw (1995), for example, state that there is considerable research indicating that the visual organisation of material greatly influences the ease of use and quality of learning. It was considered essential that screen design and usability was implemented at the highest quality possible. Guidelines for developing high-quality materials, such as those provided by McAteer and Shaw (1994; 1995) and Boyle (1997) were used in the development of the application.

The difficulties of relating the effects of sound design principles to learning outcomes are well known. However, it is argued here that the use of high quality learning materials, that were usable and founded in sound learning and design theory were essential to the perception of the quality of learning and attitude to the materials. The exploratory studies described in chapter 3 provided evidence for this. In the final study, tutors and learners repeatedly and consistently cited the design quality of the learning materials to be high and that this was important in gaining acceptance for the materials.

Criticism of methods and content in the application were surprisingly few. This was felt to be because the iterative method used and ideas gained from the results of exploratory studies were effective in establishing these features. The use of experienced subject tutors who had previous experience of non-multimedia course creation to write the domain content was also an important feature in gaining acceptance for the application. The foundations of the design and development methods used for the multimedia materials were established in the exploratory studies. The value of the initial exploratory studies in helping to create a well-designed application cannot be overstated.

Evidence for the efficacy of the application was presented in the form of various evaluation studies of the use of the material. The evaluations taken together presented a positive picture of the application. The quality of multimedia learning materials used in the study was generally rated as high by experts, students and staff in all evaluations performed in the study. It was shown that the quality of the multimedia materials themselves were important in the quality of the learning experience. Evidence for this came from a variety of sources. Tutors and students alike frequently referenced this fact in interviews and in the focus groups. There was evidence that the screen design and usability features in the application were effective in increasing users' satisfaction with the application.

Questionnaire data presented in table 8.6 supports the perception of a well-planned course that was easy to use. There was further evidence for this perception, based on interview and focus groups' evidence reported in sections 8.2.2 and 8.3.7. Learners felt in control of their own learning and mostly got what they wanted from the course. The application was rated as being of high quality and 83% of participants would recommend the experience to others.

Galloway et al (1996) investigated the influence of motivation on performance in learning. They concluded that both intrinsic and extrinsic factors were able to influence performance in learning. There was evidence from the research reported here that the quality of the learning materials led to an increased motivation of participants on the course and thus influenced the quality of learning. Interviews with staff and students frequently referred to the quality of the learning materials. In table 8.2, attitude towards study was reported as being better, compared to other courses in 15 out of 24 interviewees. Only 3 reported being less motivated than on other courses. The course was reported as being enjoyed by most learners in the interviews. The influence of the learning materials on the motivation of learners can also be seen from the focus group data reported in section 8.3.7. Students were satisfied with the multimedia application and the quality of design of the application and the quality of the media was high. Performance of the application was good and robust. Evidence from staff interviews supported this view. No tutors felt that the multimedia method led to a decrease in motivation or to worse attitudes than on other courses, The three tutors that specifically mentioned an increase in motivation ascribed it in part to the high quality of the materials.

In learning with multimedia there is a danger that learners might miss some of the motivation effects of working with and for others. They might also lose some of the other positive benefits of group working, for example the development of team-based skills. Systems based upon instructivist learning may themselves be de-motivating and may not contribute to the development of mental models and higher-order thinking. The use of multimedia as an integral part of a larger learning system including group working and involving human to human interaction was found to be effective at delivering high-quality learning, as measured in several ways. Performance, motivation and learners' attitude were found to be highly consistently throughout the study, which may be attributed in part to these methods. This way of integrating multimedia into existing educational systems was also shown to benefit tutors and was considered to be an important feature of the application.

9.4.3 Usability

Evidence was provided in the previous section that the quality of the learning materials developed in the study contributed greatly to the quality of the learning experience of participants, especially in terms of motivation. It was also important in the study to show that the materials were designed with users in mind and followed sound pedagogical, usability and screen design principles. McAteer and Shaw (1994) consider a sensible division to occur between usability (HCI) evaluation and the evaluation of learning content feedback. Reeves and Harmon also recommend that expert evaluation of learning materials consider separately the areas of instructional design, screen design and programme usability (Reeves and Harmon 1994). The relationship between usability issues and the quality of learning are complex. Boyle (1997) however states that usability (the ease of learning and the ease of use) are crucial if the system is to operate as an effective learning environment.

For these reasons expert evaluation of usability was considered to be an important feature of the summative evaluation of the quality of the application design.

Table 8.10 in chapter 8, presents the results of an evaluation by 4 experts in the area of instructional design. The instructional design review was intended to assess how well the application was based upon sound learning theory and pedagogical principles. All measures in the instructional design review were rated at higher than 3 on a 5 point scale. Experts found that learners were provided with a clear understanding of objectives of the course and were able to achieve them by using the multimedia application. The application provided clear feedback and was well-paced at an appropriate difficulty level.

The application was rated as being task-based with help provided at the correct level. The help system was the most positive feature of the application according to one expert. The use of language in the interface was appropriate and at the right level. The application was differentiated and individually configurable. Screens were well-designed and easy to understand, employing simple layout features and high-quality design features. The use of sound was also well-planned. The application was robust, operating without error. The application operated robustly all through the project, after initial installation problems were solved at some locations. Navigation, orientation and location was rated well, though system response times were sometimes a little slow. There was evidence that this may have been due to the way that sound had been configured. User tracking and recording features, such as logging in and out of the application, configuring the student model and adding users were rated as good. There was evidence from staff reports and interviews that many of the management procedures, though robust and secure, were time consuming and more efficient tools were necessary in the future.

The video evidence presented in table 8.1 supported the expert view that the application was usable. Scripted tasks such as logging in and out, locating specific information, navigating and orientating were performed well and were rated by an expert rater as being easy for learners to perform at all locations.

9.4.4 Learning presentation strategy

In this section, the important question as to what the pedagogical strategy employed in the design of the application added to the quality of learning is approached. This is important, since the structure of the application and the way that learning is supported relates directly not only to performance on the course but also to the perception of the quality of the learning provided by the application. Boyle (1997) refers to the 'instructional strategy' employed in the design of a learning application to describe how learning is organised in an application. The term adopted here is 'learning presentation strategy', since the application was designed to support construction rather than instruction and this term better reflected this.

The use of a student model to configure the presentation of the application was described earlier in this chapter. The student model configured the way the materials were used by controlling presentation of the materials, based on values of global descriptions of learners held in the model. The materials were designed as a set of stereotypical presentations that were mapped to the global descriptors. Language and cognitive style descriptors held in the student model controlled the nature and level of text and image presentation for each individual learner. These descriptors were important in making sure that presentation of information was in the most appropriate format and at a suitable linguistic level for each individual. The structure of the learning environment provided by the application however relies upon interaction between the application and individual learners.

The task, question and scaffolding descriptors used in the student model were important in establishing the structure of the context of learning. The movement away from a content-driven approach to a task-driven, context-based approach employed in the application was described earlier. This movement is in accordance with the minimalist approach recommended by Caroll (1990). Caroll describes the importance of the move away from the presentation of instruction to the active engagement of learners constructing learning in their own ways. The difference between the use of information descriptors and context descriptors will be returned to later.

Tutors not only valued the constructivist approach employed in the application, but there was evidence that they were motivated by it and that this had an influence on the quality of learning provided to students. In interviews, tutors who expressed positive attitudes to the course, stated that this was due in part to its constructivist features. The two tutors that were neutral to the course reported in their interviews that they were satisfied with the task-based constructivist ideas inherent in the application, but expressed some dissatisfaction with the support provided by the learning system and other extrinsic factors. It was important that positive features cited in the interviews were almost always related to the pedagogical approach employed in the application. Tutors were in general impressed that it was possible to apply learning theory in a practical way within a multimedia application. Several tutors expressed the view that this approach could be applied more widely in teaching and learning. The benefit to learners of the task-based approach was more difficult to measure. In interviews, learners expressed satisfaction with on-line tasks, though off-computer tasks were less valued.

In the following paragraphs, some particular aspects of the learning presentation strategy will be discussed in more detail.

9.4.4.1 Collaborative working

Collaborative working has been put forward by several authors as important in the learning process (Felder and Brent 1994; Brooks and Brooks 1993; Felder 1993). The use of collaborative group work was therefore felt to be important to the quality of learning in the application. The benefits of collaborative working have been emphasised by Felder and Brent (1994) who state that co-operative learning involves learners working together to achieve a common goal. Important elements in co-operative work are positive independence, individual accountability, face to face interaction, collaborative skills and group processing. Group working exercises in the application then, were designed to encourage those collaborative features listed above and hence the quality of learning. Explaining to the tutor was considered important as this provided an opportunity to test understanding and to obtain direct confirmation of understanding and at the same time clarify problems that remained.

The requirement that many tasks be performed off-computer in groups, supported collaborative working. It was hoped that group roles in tasks would relate to task-levels set for individual learners, for example, learners working at high levels would have a greater role in organising group activities than learners working at lower levels.

The value of collaboration however was most frequently noted by tutors rather than learners. The opinion of learners was ambiguous in this area, for example the questionnaire data showed that as many learners found group work not very useful as found it useful. However in the same questionnaire, learners stated that they enjoyed some of the features inherent in group working, for example, explaining things to others. In interviews, some learners expressed concern about the grading of group work. Group work was not assessed in the same way that individual work was. Group work could be used as evidence for satisfying Performance Criteria. Tutors however reported that they were reluctant to accept evidence from group work as evidence for an individual learner's Performance Criteria. This may have reduced the amount of invested effort by some learners. Other limitations of group work reported in interviews with learners included some group dynamic problems such as members not working effectively together, or in other groups, individuals having too great an influence over the group.

There was evidence that some learners preferred a group approach whereas others preferred a more individual approach. This may have been due to individual differences in group working preferences between learners (Keefe 1989). Felder and Brent (1994) stress the importance of group skills in the learning process and also the importance of learning group-skills as life-skills. It is argued that the quality of learning within the application was improved by the requirement for collaborative working for both these reasons. Reflection was also encouraged as a feature of group working. Reflecting on what had been learnt and explaining to others assisted in the development of meta-level skills it is argued.

Somewhat paradoxically, mirror group members (those following the non-multimedia version of the course) expressed a greater perception of isolation in focus groups than did the multimedia group, despite the greater requirement for independent working in the multimedia course. This may have been due to the requirement for group working built in to the multimedia course, the organisation of the learning materials and to the direct involvement of tutors in monitoring and target setting.

Group working has many benefits, but also there are difficulties and problems with the approach. As well as those difficulties discussed above, there was evidence that the learning environment provided for group activities may have had a negative influence on group working. The influence of the learning environment will be discussed later in this chapter.

9.4.4.2 Context

The importance of learning as a social activity, situated in a social and academic context has been made by Somekh (1996). A requirement of the application was therefore to support the situation of learning in a real context (Brown et al 1989). Evidence for the potential contribution of this approach to the quality of learning came from exploratory studies and also from the preliminary open and axial coding stages of the study.

The implementation of this principle was accomplished by considering the wider context of the use of the application. Learners followed the course to obtain real outcomes. It was considered important to design the application so that the use of the application could be related directly to satisfying Performance Criteria and providing evidence for tutors. Authentic context was supported by authentic activities, which were either complex or simple, depending on level and the group context. These activities were created by experienced subject authors and subjected to incremental peer review during development. The task-based nature of the application, the requirement for the integration of off-computer activities and the use of a wide range of other, external resources as and where considered appropriate all contributed to situating the application in the fuller learning context. Tutors on the study were aware of this objective, understood and appreciated the ideas behind it.

The need for tutors to evaluate the application in terms of the wider learning context was also important (Squires and McDougall 1996) and this was made clear to all tutors involved in the course.

9.4.4.3 Differentiation for the individual

The application was based upon the idea that an individual learning environment providing an individual experience would be beneficial to the quality of learning. A major effect was the increased autonomy provided for learners. The provision of an individually differentiated environment for learners has been recommended in the past by several authors. Jonassen (1986) suggests that learners are able to select differential paths through hyper-linked applications to structure learning for themselves. Park and Hannafin (1993) suggest that learning systems are most efficient when they provide differentiated paths related to individual differences. Bagui (1998) suggests that differentiation within a multimedia application supports working at a learners' own direction and pace of learning and the development of a constructivist approach to learning. Ayersman (1993) surveyed the relationship between learning theories and learning within hyper-linked, differentiated environments. Ayersman stressed the motivational opportunities of differentiation in learning.

The data collected in the final study supported the importance of differentiation in the quality of learning provided. For example, in the design review (table 8.10), experts considered the application to be differentiated and to be individually configurable. Some tutors stated in interviews reported in section 8.2.9 that individual configuration was a positive benefit of the course. An increase in motivation seen in learners was also ascribed to the individual learning experience provided by the course.

9.4.4.4 The use of questions

The use of differentiated question levels within the application was shown to have direct positive influence on performance, as described in section 9.3.2.4. It is argued that the use of questions had an effect on the quality of learning taking place. King (1993) describes ways that reciprocal peer questioning was used to provide additional challenges to a learner. King's question template was used to construct questions embedded within the application. Simple questions designed to test recall of facts were supplemented in the application by questions designed to test understanding and to engage learners' thought processes. Such questions were provided at all levels of the question descriptor in the student model, but were used predominately at higher settings of the descriptor. The repeated use of these kinds of questions leads to improvement in the thinking ability of students (King 1993).

Evidence for the influence of questions on the quality of learning was presented in section 8.3.6. It was shown there that learners often took on additional challenges by raising task and question levels as they worked through the course. This was taken to suggest that questions were being used by learners, not only to obtain scores or grades on the course, but also to engage in the kinds of higher-level learning activities described above by King and presented in table 9.2. In the staff interviews reported in section 8.2.9, two tutors considered question level to be the most important feature in the student model.

Table 9.2
King's (1993) question template used to design questions for the Application of Number course
What is the main idea of..... What if..... How does.....affect..... What is the meaning of..... Why is.....important What is a new example of..... Explain why..... Explain how..... How does.....relate to what I've learned before What conclusions can I draw about..... What's the difference between..... and ..... How are..... and ..... similar How would I use ..... to ..... What are the strengths and weaknesses of....

The benefits of considering question type were also apparent from the open and axial coding stages of the study, described in chapter 7. In the questionnaire answered by FE staff, question type was considered to be an important feature to be included in a multimedia learning application (see Appendix 14). There was also supporting evidence for in the expert review, summarised in table 8.10, Experts considered that the instructional design was based on sound learning theory and principles, the difficulty level of this application was appropriate and on-line questions and tasks were good. These taken together support the view that the pedagogical influence of questions in the application contributed to a high-quality learning experience.

9.4.4.5 The use of scaffolding

The provision of scaffolding and help differentiation within the student model was shown in previous sections to have a positive influence on learning quality. The use of scaffolding was considered to be an important feature of the application as it was related to ideas about how new learning is integrated into existing knowledge. Scaffolding was used within the application by setting the entry point for integrating new skills and providing the appropriate tools to solve problems. Minsky (1986) describes frames or schema that determine how learning is structured, providing templates upon which new ideas can be hung. K lines are described by Minsky (1986) as methods which can be used to solve new problems. In the application, the tools required to solve problems corresponded to Minsky's K lines. Minsky suggests that keeping useful tools close at hand assists in problem solving. This was achieved in the application by structuring the provision of problem solving strategies and tools.

Layered scaffolding was used to support the structuring of information, by providing templates that helped learners to structure and integrate knowledge at the appropriate level. This could also be considered in terms of Vygotsky's zone of proximal development. Learners are provided with freedom to solve problems within their zone of proximal development, until they are able to go no further. Only then is additional support provided for a learner in order to solve the problem (Vygotsky 1986).

These ideas were implemented in the application in the form of layered scaffolding linked to context. At higher levels, problem solving was under the control of learners. It was assumed that frames were already well-structured and linked to a rich set of K lines. At lower levels, frames were assumed to be less developed and needed to be made more explicit, with links to appropriate K lines created by the author and suggested by the system. In this way problem solving was kept within each learner's zone of proximal development at the appropriate level. The student model was used to configure the way the layers were revealed for learners. At higher levels learners were able to reveal the layers of support themselves, searching for K lines and storing cognitive references to them. At lower levels, K lines are made explicit and linked to templates provided within the application.

Group collaborative work was also considered as a way of providing a different sort of scaffolding. The kinds of discussion that took place in group work would help learners at different levels in linking what they already knew to the wider context of the group knowledge. The evidence that learners were able to move up the question and task-level scale (see table 8.8) suggested that learners were developing new skills and widening their zones of proximal development.

There was evidence from the preliminary study reported in chapter 7 and from the exploratory studies reported in chapter 3, that the provision of configurable help levels contributed to the quality of learning. There was supporting evidence from the expert evaluation (table 8.10) that help provided was good and at the correct level. Learners cited the help system as being good and simple to use in student interviews (table 8.2). In the questionnaires presented in table 8.6, the majority of learners considered that the help systems provided were useful.

9.4.4.6 The use of tasks

The use of tasks in the application was important in the quality of the learning provided by the application. Tasks were used in the application in several ways. At a simple level they were intended to provide feedback on progress for learners, allowing them to measure and record their progress on the course. Tasks were also used to develop problem solving skills in learners, to help in the development meta-level skills. The use of scaffolding and collaborative work was important in the development of such skills. The requirement to undertake off-computer tasks that involved activities such as presenting findings of surveys and explaining results to others was intended to help develop meta-level skills.

A task-based approach was also important in motivation, which was supported by requiring the active seeking of problem solving skills rather than a passive receiving of information presented. Cognitive conflict was described by Piaget (1985) as a student's drive to learn when his/her cognitive structures are insufficient to handle a situation. An important instructional principle adopted in the application was that cognitive conflicts should be introduced deliberately to motivate learning, and that the student model be used to establish the task, question and scaffolding level to best accomplish this. Motivation is improved according to Stoney and Wild (1998), when there is optimal mismatch between a user and what is to be learned. This has an effect on motivation, though motivation will be negatively affected when the mismatch is less than optimal (see table 9.3).

Table 9.3

The relationship between cognitive demand, motivation and environment (Stoney and Wild 1998)

Cognitive demand	Motivation	Environment
Minimal	Low	Unchallenging
Optimum	High	Challenging
Maximum	Low	Overwhelming

Tasks that are insufficiently challenging for an individual learner will de-motivate them (Stoney and Wild 1998). Tasks that are over demanding will de-motivate learners. When tasks and the learning environment are configured to suit the individual, then mismatch is optimal and motivation is high. The use of the co-operative student model was intended to increase motivation by providing a configurable optimal mismatch. There was evidence that learners on the application were highly motivated. It is suggested that configuring the learning environment to optimise cognitive conflict was responsible to some extent for this fact.

9.4.5 Summary: multimedia materials

In the previous section, evidence for the influence of the multimedia materials on the quality of learning was presented. Subject content, design features, usability and learning presentation strategy were discussed in relation to their influence on the quality of learning. It is suggested that, in consideration of the evidence presented, these features of the multimedia materials contributed in to the quality of learning experienced. In the next section, the influence of the management of learning on the quality of the learning experience is assessed.

9.5 The management of learning

It was argued earlier in this chapter that an important stakeholder in the learning process was the educational system itself. The management of learning is carried out by tutors, who are front-line managers and course team members, and the systems that have been established to facilitate the learning process. In one sense it depends on features of the local environment that control learning, such as the classroom environment, the facilities and resources used in learning, and in a broader sense it includes the institution-wide systems that have been established to manage and support learning processes. The former local systems are referred to here as the microenvironment, and the institution-wide global systems as the macroenvironment. There is naturally a relationship between these two environments, but it is important to assess the influence of each individually on the quality of learning.

In the following paragraphs, the influence of the application on the management of learning, and the influence of tutors and environments on the quality of learning are discussed. Important ideas about the evaluation of the application in relation to the objectives of learning managers are then discussed.

9.5.1 Tutors

It was suggested earlier that tutors should be considered as a major stakeholders in the Application of Number course, providing an important interface between learners and the educational system. The role of tutors in the Application of Number course was important for several reasons. As the main 'figure of authority' or representative of the educational system, the tutor is instrumental in learners' perceptions of the value of the application. It is argued in the following section, that, in those cases where tutors have a positive attitude to the application and readily accept the evidence provided by it, students are more likely to engage with the application seriously. In cases where the tutors did not value the application, or evidence provided by the application was not accepted fully in order to qualify learners, learners had a lower perception of the application and engaged in it in a less than fully motivated way. For these reasons it was not possible to consider the evidence for the quality of learning provided by the application in isolation from the effects of the tutor.

The study also found evidence that not only were learners influenced by the tutors' attitudes to the application, but also that changes in the tutors' attitudes were caused by the way they used the application with learners. The quality of learning provided by the application then was closely related to how tutors engaged with the learners in their use of the application.

The importance of the tutor as the manager of learning on the course can be seen from the list of activities recorded in tutors' reports (see section 8.2.10).
The list presented there suggests that the role of the tutor as the direct manager of learning on the Application of Number course was always extensive, despite the flexibility of delivery method. There was evidence from the video sessions that there was an effect of tutor involvement on the way that students used the application. Evidence here was incomplete as only one session was recorded. It was possible however to see a relationship between tutors' and students' attitudes from other sources as described below.

Tutors' attitudes was rated from interview data and staff reports by experienced raters who were not involved elsewhere in the project. Two raters were asked to read staff reports and view videos of the staff interviews and to assess the quality of tutor engagement. Tutor attitude was rated on a scale of 1 to 5, where 1 was a negative or poor attitude and 5 was a good or positive attitude to the application. The average of each rater's score was used as a measure of tutors' attitudes Students' attitudes were measured based upon an average of selected attitude measures on questionnaire data presented in table 8.6.

Table 9.4 Relationship between students' attitudes and tutors' attitudes to the application at 6 locations		
Location	Students' attitudes 1-5	Tutors' attitudes Mean - (range) 1-5
Location 1	3.1	1.5 (1-2)
Location 2	3.8	4.0 (4-4)
Location 3	4.1	5.0 (5-5)
Location 4	3.9	3.5 (3-4)
Location 5	3.6	3.5 (3-4)
Location 6	3.6	4.0 (3-5)

It is not possible, based on the data in table 9.4, to perform a statistical analysis on staff's and students' attitudes at the six locations. However, the results are strongly suggestive that staff's and students' attitudes are indeed related. The location with the highest students' attitudes also had the highest tutor's attitude. The location with the lowest students' attitude, location 1, also had the lowest tutor's attitude. From the video evidence at this location, it could be seen that no introduction to the session was provided, the quality of effort by learners was low, and users' attention, room organisation and students' organisation were poor. At location 3, where staff's and students' attitudes were rated highest, the video session began with a motivational introduction. Learners invested a large amount of effort in performing tasks and the organisation of the session was good. At both locations 1 and 3, student/tutor interaction was low during the session. This suggests that in a well-organised session, such as location 3, with well-motivated learners, the direct involvement of a tutor is not necessary to ensure a high-quality session.

There was also evidence from focus groups and interviews that the involvement of a tutor in providing additional help and explanation was important to learners. This however did not have to take place in computer sessions. It was important in group activities and in one-to-one staff student interactions also. It is interesting to note that students' perceptions of working with a tutor on the course was high. In the interviews, almost all learners considered that they worked as frequently or more frequently on the course than on other courses (see table 8.2). The focus groups suggested that both tutors and students found that working together on the course to be a positive feature that influenced students' motivation. Tutors reported in interviews (section 8.2.9) and staff reports (section 8.2.10,) that their involvement was a positive factor in all stages of the learning on the course.

Staff diaries provided a great deal of information as to how tutors followed the course with learners. It was interesting that tutors followed the course very differently in different locations. The duration of the course ranged from 4 to 6 weeks (see table 8.9) which was well-within the target set for the section covered by the multimedia materials. It was a requirement of the course that each participant should meet at least twice with tutors during this time in order to set targets and review progress. Most tutors reported short meetings more frequently, at least once per week. Group sessions and lectures were also reported. Group sessions lasted between 30 minutes and one hour. Lectures lasted one hour and were delivered weekly or fortnightly.

From staff diaries it was clear that a relatively large amount of time (between 3 and 7 hours each week) was reported as being spent in setting targets and configuring the student model for individuals. Approximately one half of this time was spent in student contact. Much of this time was reported as time spent accessing data, reviewing physical evidence of student work, and only some of it was spent in discussing progress in the light of physical evidence and testing students' understanding. Tutors were reluctant to accept evidence from computer log files without additional corroborating evidence.

Tutor involvement in the ways described above, contributed greatly to the quality of the overall learning experience, but placed great demands on staff time. Tutors were prepared to give this time in the context of the study, but often expressed concern over the time taken in such activities, for example in the staff interviews. It would be important in future that staff be provided with tools to assist in this process, and that additional training be provided to help in the efficiency of the process. Tutors agreed that they were likely to accept computer-based performance evidence in the future, to reduce the amount of time spent reviewing physical evidence in target setting and progress reviewing. Lack of confidence in the computer-based systems had contributed to the reluctance to accept such evidence in this case.

Tutors' involvement in organising group work was also important. Due to the small numbers of learners, there were occasions where some levels of group members were not represented in the groups. On these occasions tutors often played a role in the group, usually a high-level role, for example as organiser (see section 8.2.9).

In summary, there was a great deal of evidence from this study that the involvement of the tutor in the course was a major factor in its quality. The significance of this finding will be discussed later in the concluding section of the chapter.

9.5.2 The learning environment

In order to understand how the management of learning was related to the quality of learning, the influence of the learning environment needs to be understood. The learning environment is defined here as the physical, organisational and social context in which learning takes place.

The primary environment within which a CAL application is used is considered here as the microenvironment of the application. This directly relates to the local environment, the classroom, the hardware, software and networks upon which the applications were run, the staff and students using the application and the day-to-day support for the application.

Factors related less directly to the use of the CAL program, yet contributing to how the application is used are referred to here as the macroenvironment. This includes institutional and higher-level factors, such as the support provided for developing and integrating multimedia and the internal and external influences and pressures on the use of Information and Learning Technology (ILT).

The perception of the quality of learning provided by the Application of Number course was influenced by these environments. The influence of these contexts on the evaluation of the application is discussed in the next section.

9.5.2.1 The microenvironment

The microenvironment is in part created by tutors and students, who may also be considered as recipients or users of the microenvironment. Despite this added complexity, it was possible to draw some conclusions about the influence of the microenvironment on the quality of learning in the study. There was evidence about the direct environment from the video of a limited number of sessions, also from tutor reports and from less-direct evidence such as focus group discussions, staff and student interviews and questionnaires. It was important to know specifically, in what ways the microenvironment was having an influence on the quality of learning. This was important to allow for any differences between locations and also to understand how the microenvironment was influencing results in the study.

It became apparent early in the study that the learning environment was indeed important in the perception of quality of the whole learning experience. Several categories and variables repeatedly and consistently identified in the axial and open coding stages of the study related directly to the learning environment. These included the quality of computer hardware, computer software, network systems and technical support available. These factors were rated highly in almost every case in the early preliminary stages of the final study. For this reason, the locations selected for the final study all possessed high-quality support systems for CAL. Technical and learning support staff were also experienced in supporting CAL users in all locations.

Computer sessions took place in a variety of teaching and learning environments including learning centres, libraries, specialist computer rooms and classrooms.

The learning microenvironment however was also seen to be related to the way that learning was managed in sessions. The influence of tutors in this area has already been discussed. It was also related to how students used the microenvironment as they contributed to the creation of their own learning environment. It meant that it was not possible to control the microenvironment to any extent, only to perhaps understand how it could influence learning.

Light, noise and space were identified as important physical variables that influenced the quality of the learning environment for the delivery of multimedia applications. The influence of these factors on the learning environments in the study was measured in a variety of ways. Video data provided a snapshot of a single session at four locations (see table 8.1). In these locations, noise level was high or medium in all places. The space provided by the environments were roomy or adequate except for one location. The lighting in the rooms was adequate or good and there was no evidence of glare on computer screens. Tutors were also asked to comment in their reports on the quality of the physical environment. No tutor considered this to be a negative factor in following the course.

The direct learning environment was established in a balance between the learners, the conditions in the learning room and the way the tutor controlled or influenced the session. There did not appear to be any simple relationship between the level of student-student interaction and student-tutor interaction in sessions. It did appear from video evidence that noise level increased as off-computer activities, often involving interaction between learners, increased. Whether this produced a higher or lower-quality environment was not clear.

The factors that determined the quality of the microenvironment were interrelated to a high degree in this study and it was not possible to show causal relationships between them. It was possible however, to make some general conclusions about the influence of the microenvironment. There was evidence from student interviews that open learning environments in general were valued by learners, providing features that helped learners to work at their own pace and to work flexibly in learning centres (section 8.2.2). Some learners however reported that using learning centres detracted from the course. There was ample evidence that the physical environment provided at all locations, except location 1, was good and that provision of the correct support environment was important for staff and learners. Technical support, hardware and software were considered by tutors to be important factors in the quality of the learning provided. Being part of a well-organised system was felt to be an important factor by students in flexible working and working on their own.

The influence of the wider ILT learning environment provided by the institution, the macroenvironment, on the quality of learning is considered in the next section.

9.5.2.2 The macroenvironment

The macroenvironment for Information and Learning Technology (ILT) within an institution at any time is determined by the institution in response to a range of internal and external factors. Funding is an important factor in ILT provision. Since incorporation in 1992, FE Colleges have been financed by the Further Education Funding Council (FEFC) who influence college policy and strategy. The Higginson report (FEFC 1995) established guidelines for the use and integration of ILT in FE colleges, including the provision of the Internet and multimedia for learning. These guidelines recommended large investment in ILT in colleges, including the establishment of centres of excellence, a broad bandwidth FE learning network and the establishment of an ILT staff development programme. The report approached issues of cost effectiveness, the cost of alternative technologies, the potential of working with commercial organisations and the cost of falling behind. It is fair to say that this report was important in establishing the underlying philosophy for the provision of ILT in colleges.

Other important factors in establishing the macroenvironment include government policy on FE and ILT, local factors such as demand for courses and competition from other institutions, commercial and marketing influences, such as student recruitment, and student retention and pass rate, which directly influences funding. Each institution is required to publish a strategic plan containing a mission statement. The strategic plan establishes the institution's direction in a range of areas including ILT. The microenvironment within an institution is established in order to deliver the institutional objectives as set out in the strategic plan and mission statement (see for example, Waltham Forest College 1997). The macroenvironment is also determined in part by the skills, experience and personalities of the staff in the institution. Managers at all levels in the institution have a significant role in establishing the macroenvironment.

It was not possible within this study to examine the complex relationship between the microenvironment and the macroenvironment for any institution. It was however possible to identify issues within the macroenvironment that were supportive to the quality of the learning experience provided by ILT. Thus it is suggested that certain factors within the institutional macroenvironment would be either supportive or not to the implementation of a microenvironment to support ILT. The support an institution provides is likely to be reflected in tutors' motivation and for reasons suggested earlier, in students' effort and motivation. It was not possible to obtain any direct measure of institutional support within the limits of this study. However, staff report guidelines included general questions about their institution's attitude and support for instructional technology, as referenced in section 8.2.12. It is argued that the tutor's perception of the quality of the macroenvironment provided is important, since it is likely to influence motivation and attitude to ILT as described above.

Evidence for institutions' attitudes and approach to ILT was provided in section 8.2.12. It can be seen from tables 8.11 and 8.12, that there was on average a fairly positive perception of the institutional philosophy and support for ILT. Five of the six reports stated that institutions had an ILT policy for example. In all locations there was a quite good perception as to the level of physical support for ILT provided.

Examination of table 8.12 provides evidence from staff reports of tutors' perceptions of the different approaches to ILT strategy at some locations. The provision of local support may be contrasted with central provision and an individual approach contrasted to team-based approaches. Another interesting comparison is the notion of an evolutionary approach to change reported at locations 3 and 4, compared to a more revolutionary approach reported at location 2.

Examination of tables 8.11 and 8.12, however, suggests that at location 1 there was a lower perception of institutional philosophy and support for ILT. At this location the macroenvironment was judged by tutors to be not supportive to ILT provision. At this location tutors and students attitudes were also the lowest and the microenvironment provided at the video session was judged to be the poorest. This provides some evidence for the relationship between the macro and microenvironment, or at least for a relationship between the perception of the macroenvironment and the actual microenvironment.

It was evident from the early stages of the project that the attitude of staff to ILT was related to the institutional support provided, and that these factors were important in the quality of learning. The provision of adequate resources is clearly important in the provision of ILT. The institution however, needed to see some direct benefit in order to provide the necessary support for ILT. The provision of high-quality learning environments required the allocation of large amounts of scarce resources at the expense of others. This can result in conflict between the stakeholders in the ILT process and other areas requiring resources. Factors that relate to levels of institutional support for acquisition, development, training and use of ILT is likely to influence the integration of ILT at an institutional level and thus influence the quality of learning.

9.5.3 Summary: The management of learning

The quality of the local and institutional learning environments were shown to be related to the quality of learning in the previous discussion. This was related to the complex relationship between tutors and learners and the learning environment, which included the learning materials and their support. Evidence was provided to suggest that where the microenvironment and macroenvironment were supportive to ILT, this had a positive influence on tutors' and learners' attitudes and hence on the quality of learning.

9.6 Discussion

The use of information technology in the delivery of learning is a phenomenon which is increasing with the development of cheap and powerful software and hardware systems. A recent development in educational technology is the use of multimedia in the delivery of learning. Multimedia is a rich powerful tool which has the potential of providing high-quality open and flexible learning. There is evidence however that multimedia has not provided this, to the extent to which it has been predicted (Tergan 1997). Another development in educational technology involves techniques in user modelling in the field of AI. These have been used to present and configure information based upon the individual requirements of users. In the study presented here, the technologies of multimedia and AI were combined in an application intended to provide a unique learning environment for individual learners.

The study presented in this and the previous three chapters was intended to approach the central research question, how is the quality of learning affected by using a configurable multimedia learning application based on an adaptive co-operative student model of learners' characteristics?

In order to answer this important question it was necessary to look not just at learners and their use of the application, but also at the other stakeholders in the process, tutors and educational systems. An understanding of what was meant by the quality of learning was also necessary.

The evaluation of the application was carried out based upon ideas developed in a preliminary study of the area, referred to as the open and axial coding stages of the project. In this preliminary study the relationship between the many variables in the project was established and refined. Based upon this information, the results of the evaluation were analyzed and placed into the context of the research question.

A large amount of data was obtained in the evaluation and an important part of the evaluation was the structuring of this data as it related to the research question. The main categories important in the research question were identified as being the student model, the learning materials themselves and the full learning environment, including learners, tutors and the educational system.

Evidence for relationships between the categories obtained in the study was presented. It was hoped to place this into a fuller context, including underlying educational theory and the social context of the phenomenon. In this way it was hoped that the richness and complexity of the phenomenon in its full context might be understood.

The results of the evaluation of the final study suggest that the multimedia application developed had a positive effect on the learning experience for the students involved in the project. There was also evidence that the staff involved benefited from involvement. It was shown that using the materials caused positive changes in tutors' attitudes to the use of AI student modelling techniques in learning. It was also shown that the co-operative adaptive approach involving tutors at all stages of the process was a major cause of this attitude change.

Learners performed well using the application and a range of evidence was presented to show that the learning environment provided was rich enough to provide motivation and challenge to all learners, but was also supportive and able to present challenges at the most appropriate level. The use of task, question and scaffolding level were shown to be important in this process.

It was found that the evaluation of the rich and complex system provided by the application could not be undertaken in isolation from its full learning context. In order to understand this more fully, the learning macroenvironment and microenvironment were considered. These provided the interface between learners and their learning. It was possible within the study to suggest causal relationships between some factors within the macroenvironment and the quality of the microenvironment provided. Where objectives and understandings about ILT were shared between stakeholders, the quality of learning was likely to be better than where there were differences in this understanding. The macroenvironment within an institution not only provides support for the physical use of an application, but also determines the philosophy and attitude to the use of ILT and the way that change is dealt with in the institution. These factors influence the attitude of staff to the use of ILT which has a profound influence on how it is used and evaluated. An important conclusion from the study was that any evaluation of CAL that does not take into consideration this full context is likely to be flawed, since there was evidence of a relationship between learning environment and the attitude of staff and students to the quality of learning provided by the application.

The results of the study overall were taken to indicate that a combination of multimedia and user modelling techniques using an approach that made the best use of human and AI was able to produce a rich and high quality learning experience.

It is argued that there was benefit for all stakeholders involved in the application. Learners described a rich and fulfilling learning experience and obtained good outcomes, tutors were fully involved in the learning process and secondary benefits for them included confidence building and the development and use of new transferable ILT skills. The third stakeholder, the educational system was also likely to benefit from the use of the application. Although direct evidence for this was not available from the study it was suggested that the provision of such systems were likely to support institutional ILT strategy and have the potential to increase staff and student satisfaction, leading to improved student recruitment, retention and results in the longer term. Certainly there was a great deal of evidence from the preliminary study that college managers welcomed the integration of ILT into the curriculum and considered it to be a benefit.

In the next chapter, the implications of these findings are considered and related to the project as a whole. The potential for the student modelling approach is explored and suggestions for future research are considered.

Chapter 10

Conclusion

10.1 Reasons for undertaking this research

The work presented in this thesis has been developed in an attempt to address the practical need to produce high-quality and effective multimedia learning materials. This was motivated by several factors and in the next section some of these will be discussed.

Since the advent of multimedia and the CD-ROM, the positive motivational aspects of multimedia have been apparent to the author. Working in computer learning centres in a college of FE, it was easy to see that the focus of learners' attention was not the word processor they were using, but the one or two multimedia development computers in the corner of the centre, being used to develop early attempts at multimedia computer-aided learning (CAL) applications. It soon became apparent however, that the kinds of material that were able to capture the imagination of learners were not readily available, nor simple to create. The question naturally arose as to the reasons for this.

Other influences were also important in deciding to undertake this project. Student numbers were becoming higher and staff numbers fewer in colleges of

FE. Contact time with students was becoming less as college management continually increased the ratio of students to each member of staff. The perception was that Information and Learning Technology (ILT) could be used to replace teachers with 'stand alone' training programmes that could be run from the library, or even the home, with little or no input from the tutor. This led very much to a feeling of low morale and even helplessness, and certainly to a low perception of the value of ILT.

Perhaps not surprisingly, multimedia was having little, if any, impact on the quality of learning in any of the many colleges of FE involved in this study. This fact was echoed at meetings of the National Information and Learning Technologies Association (NILTA), the Further Education Development Agency (FEDA) and the National Council for Educational Technology (NCET) (now BECTA). Despite great efforts by these organisations and considerable investment by colleges, multimedia was not delivering its promise.

When attempts were made to integrate ILT into existing courses, or perhaps more frequently to use a multimedia course to replace an existing course, results were poor. Tutors almost universally evaluated applications as offering the poorest of learning environments. Often materials were instructionalist in their design, using rote memory and providing little challenge to learners. From a personal perspective, students and staff were ill-prepared, poorly supported and under-funded for the work. Objectives were not made clear and the effort invested in the work was poor. This, not surprisingly, led to poor results and a reluctance on the part of all stakeholders to invest time, effort and resources into the process.

For reasons such as those described above, the use of ILT in the curriculum was often supported inadequately by the institution, possibly because of the low-quality of what it was delivering and a 'vicious circle' was produced of poor quality perception leading to poor quality use and poor quality support. In many cases training was either not provided, or provision not directed towards the right areas. Support was under-resourced and low quality learning environments often resulted. This situation is still common in many FE institutions today.

The development of multimedia learning materials such as those described in this work was intended to support the move towards the development of a richer, more effective multimedia learning environment. It became clear from this project, that to fulfil this aim required an understanding of a wide range of complex issues related to the full context of the use of ILT in FE. This project was undertaken as a stage in this ongoing work.

10.2 The findings of this research

The research described in this thesis demonstrated that the quality of learning provided by a multimedia application is improved by the use of a co-operative student model of learner characteristics. The research consisted of two exploratory studies, two experimental investigations and a large scale study on the use of an individually configurable multimedia application. It is intended in this section to describe the findings of this research, to place it in context and to show the contribution of this research to knowledge.

10.2.1 The quality of learning

The central theme of the research was to relate the use of a student model in a multimedia application to the quality of learning. In order to achieve this, the concept of the 'quality of learning' had to be understood. Although there are many references to learning in the literature, there is no clear definition of what is meant by the quality of learning. There would seem to be at least two reasons for this. The first reason is the difficulty in defining learning. The second reason is the difficulty in measuring its quality, given that it is possible to agree on what precisely learning is. Some authors, for example Reeves (1992) explain what learning is not. He argues that learning is more than the difference between pre-test and post-test scores, however Reeves does not provide an explicit definition. Implicit definitions of learning can be found in the work of many authors. For example, Atkins (1993) presents an overview of the relationship between learning and learning theory in the design of multimedia. Others present methods to measure aspects of the quality of multimedia in learning (Boyle 1997; McAteer and Shaw 1994; Squires and McDougall 1996), thus assuming an implicit understanding of the quality of learning. An understanding of the quality of learning in multimedia, however, requires the simultaneous application of these ideas in a specific context (Squires and McDougall 1997).

An important outcome of this research was an understanding of the meaning of the central theme of the research, 'the quality of learning'. Rather than provide a simple definition of learning or its quality, a narrative was produced and presented in chapter 9, that described how the many complex interactions identified in learning with an individually configurable multimedia application, were related together around the central idea of quality. A range of evidence was obtained in real learning contexts and this was presented in chapters 8 and 9. The relationship between the application, the users of the application (the stakeholders), and the quality of their learning experience was the subject of the narrative produced. How the grounded theory approach employed was effective in this endeavor is discussed in section 10.4.

10.2.2 Language

In chapter 4, the effect of language on performance in multimedia learning was investigated. The language level of the multimedia presentation was found to influence performance for those learners where language skills were poor. Significant differences in performance were found for the NVQ user groups following presentations with different language support ($p<0.05$). NVQ learners had scored significantly lower on the language test than staff or HND groups.

No significant difference between staff or HND users following presentations with different levels of language support was found. These groups had scored highly on the language test. This was taken to indicate that learners with poor language skills perform better when information is presented in a multimedia application at the appropriate level. These findings were important in the context of the overall research project, since they established the importance of language as a component of a student model of learners' attributes.

The importance of language in learning is clear to many educators (Barron and Atkins 1994; Petre 1995; Blank and Solomon 1969). Despite this, there are few reports of language being used to support the users of multimedia computers, either in the interface, or in the presentation of learning. It is sometimes assumed that the use of multimedia *per se* is sufficient to support deficiencies in language skills.

In the experiment reported here, language differentiation and the provision of additional support was found to be effective at supporting learners with weaker language skills and improving their performance. In this way the provision of language support had a positive influence on the quality of learning provided by the application.

10.2.3 Cognitive style

In chapter 5, the effect of cognitive style on performance in multimedia learning was investigated. When Bi-modal learners were excluded from the study, a significant difference between performance in supported and non-supported sections of the course was found ($p<0.05$) for Verbalisers and Imagers. Learners at the extremes of Riding's Verbaliser-Imager dimension performed better when information was presented in a form that supported their preferred learning style than when it was presented in a form that did not support their style. These findings were important in the context of the overall research project, since they supported the use of cognitive style as a component of a student model of learners' attributes.

Cognitive style is widely considered to be important in learning (Entwistle, 1988; Riding 1991a; Kolb 1976; Clarke 1993). For example, Ayersman (1993) found a negative effect on learning when styles of presentation and learning were mismatched and a positive effect when they were matched, which supports the findings reported here.

Pillay et al (1998) failed to find significant differences in the performance of learners with computer-based materials matched and mismatched to their cognitive style as measured by Riding's CSA test (Riding 1996). They suggest that a reason for this may have been that the information content of diagrams used to support Imagers was low. It is likely then, that the difference between the findings reported in this research and Pillay's findings can be attributed to the fact that the multimedia presentation employed in this study was able to provide greater information content to Imagers and therefore support them better.

Another difference between Pillay's study and the research reported here was in the handling of Bi-modal learners. These were excluded from the study reported here. Pillay also reports excluding Bi-modal learners in her study, but the Bi-modal range adopted by Pillay (0.99 - 1.09) was less than the Bi-modal range employed in this study (1.02 - 1.37). It is likely then, that Pillay excluded a smaller proportion of learners than the 33.3% excluded in this study. Bi-modal learners perform well irrespective of presentation mode and were shown to influence the results in this research. Therefore, excluding a smaller number of Bi-modal learners from the analysis of the results is likely to mean that any differences in performance would appear to be non-significant.

Valley (1997) also approaches issues relating to learning styles and courseware design. She asks whether learners should be able to learn in their preferred way or whether learning styles might be best used to impose additional challenge on learners by mismatching learning style and presentation style. The research findings reported here support the view that if performance in the domain is the important issue, then matching preferred style to the delivery style is the best option.

The results of the experiment reported in chapter 5 support the view that the richness of multimedia and its potential for incorporating high-quality visual content make it a prime candidate for delivering learning configured in a way appropriate to individual cognitive styles and thereby contributing to the quality of learning.

10.2.4 Student modelling

Evidence was presented in section 9.3 and the following sections that the student model developed in this research was effective in providing an individual and high-quality learning experience.

The importance of an individual learning experience has been stressed by Ohlsson (1993). The strongest argument for the use of computers in education is their potential to individualise instruction (Ohlsson 1993). For Ohlsson, this means that decisions that affect instruction are taken by the computer, based on a knowledge of individual learners. In the approach adopted in this study however, it was found that learning decisions could be shared between learners, tutors and the computer. In this way, it is argued, it was possible to provide a constructive learning environment and yet still benefit from the student modelling approach and the potential to individualise *learning*, rather than instruction.

Even though research on Intelligent Tutoring Systems is over 25 years old, very little attention has been paid to the issue of evaluation according to Bloom et al

(1997). In this study, an individually configurable multimedia application was extensively evaluated. An important finding of this study was that, despite the complexity, it was indeed possible to perform an evaluation of the use of an individually configured multimedia system in a real learning context. Qualitative and quantitative evaluation methods were integrated, using a Grounded Theory approach, to provide evidence of the effectiveness of the multimedia and the student modelling approach employed.

The difficulty of student modelling has been emphasised by almost all researchers who have used the method. Because of the complexity of student modelling, Intelligent Educational Systems are often driven by what is possible rather than what is desirable according to Cummings (1993). This position has changed little in five years. 'Systems rarely attempt to model anything beyond the learner's current knowledge in the target domain .... it is very, very difficult to build a learner model that is sufficiently rich to support a diverse and effective interaction with the learner'. (Cummings 1998)

The complexity of the student model is central to this problem. As Self (1990) explains: 'The student modelling problem expands, from computational questions, to representational issues, through plan recognition, mental models, episodic memory to individual differences – to encompass, it would seem, all of cognitive science' (Self, 1990). Many consider the problem to be overwhelmingly difficult (Self 1990).

Different types of student model have been described by several authors (Boyle 1997; Cummings 1998; Vassileva 1996). The most important type of student model in use and suitable for use in this research were overlay models and models of learners' attributes (Ohlsson 1993), as explained in chapter 6. It was found in this research that the use of a model of learners' attributes was effective in configuring learning for each individual.

The student model adopted in this research was a co-operative model. Bull and Smith (1995) describe the use of a co-operative student model. Perhaps the most important reason for the selection of the student model type used in this study was the requirement that the application should support constructive learning. Using a co-operative student model of learners' attributes was found to support constructive learning.

The model developed was both configured and adapted co-operatively. It was found to be simple to understand and inspectable. This was effective in involving users and tutors in configuring and adapting the model, supporting interaction with the model directly. The model, being based on learners' attributes, was separate from the domain. This made it readily transferable to other domains. The model was based upon tasks and questions and included scaffolding and help configuration. In this way it was possible to support a range of constructivist ideas and yet still be able to present information optimally for individual learners. The global descriptors that were used to configure presentation were based on powerful global descriptors of learners, language and cognitive style which were shown to be effective in learning.

Evidence was found, presented in section 9.3, that the individual configuration of learning using a student model described above, provided an appropriate balance between support and challenge for learners. Information, instructions and help were presented at the best language level for learners and in a form that supported rather than challenged their individual cognitive style. The student model was used to control the presentation of tasks and questions to influence the level at which learners could obtain maximum benefit as described in section 9.3.2.3 and section 9.3.2.4. The provision of additional help or scaffolding was also under the control of the student model. The use of scaffolding is discussed later in this chapter. Tasks, questions and scaffolding together were shown to provide a rich, differentiated learning environment where learners could explore and construct rather than receive instruction. The most appropriate entry level to tasks, questions and help was provided, under the control of the student model. In this way the need to challenge and motivate could be balanced against the need for support.

10.2.4.1 The role of the tutors

Evidence was presented in section 9.3.3 and 9.4.4.1 that active tutor involvement in the use of the multimedia course was central to the quality of learning provided by the application. This is in accordance with Atkins (1993), who suggests that it is possible to 'readmit the tutor as part of the learning experience'. Five years later, Hartley stated that intelligent tutoring systems tend to 'limit the initiatives given to the learner with the program itself managing the interactions and instructional decision making' (Hartley 1998). Thus the tutor has not, in general, been readmitted into the learning process.

In the co-operative form of the student model employed in this research, the most significant decisions were made by the learners and the tutors and were then implemented by the application. The application of appropriate challenge, motivation and feedback was in the hands of the human intelligence and involved tutors in the process.

The involvement of tutors in configuring the values of the descriptors used in the model was an important feature of the application. Not only did this make the best use of human intelligence in configuring learning, it also involved students and tutors in the human, social aspects of learning, so important to its quality. It was shown that the use of targets involving a range of group activities and off-computer tasks and the use of different types of question to structure and enrich the types of challenges imposed, added to the quality of the learning environment.

The effectiveness of the co-operative student modelling approach was explained in terms of providing learning at the appropriate level, which involved establishing an optimum mismatch between learners and what needed to be learned (Stoney and Wild 1998). This was linked to the ability of learners to work within their zone of proximal development within the application (Vygotsky, 1986).

There was also evidence presented in section 9.3.3.1 that learners were taking on progressively greater challenges as they progressed through the course. This could be seen from changes in the configuration of the student model over time. These were, after initial adjustments, always from lower, more supported levels, to higher, more challenging levels. The influence of tutors in negotiating targets was important here. A major concern in adapting learning is that it might lead to learners working at the most comfortable level with little additional challenge imposed. By involving tutors in motivating and setting targets, challenge was provided for those that would benefit from it.

10.2.4.2 The components of the student model

The attributes of learners that were used in the student model presented in this research were selected to represent a balance between the need for automatic configuration of variables, as in language and cognitive style and their co-operative configuration, as in task, question and help levels. In this way important aspects of learning that could best benefit from behind the scenes control were differentiated from those aspects of learning that required human input. The results show that, by and large, a balance was achieved that supported a high quality learning experience that was of benefit to all the stakeholders involved in the process.

Section 9.3 presents the contribution made to the quality of learning by each of the individual components of the student model.

Little research has been reported on the use of language as a learner attribute in student models, despite the universal acceptance of its importance in learning. An important finding of this research was that language could be used effectively in student models. A method of language testing and language differentiation was presented that was shown to be effective in controlling the presentation of information. Another benefit of including language in the student model was the positive influence this had on tutors.

There have been more attempts to use cognitive style to control the presentation of learning. De Diana and van der Heiden (1994) used individual learning styles to configure the presentation of information in electronic books. Their approach was based on a questionnaire to distinguish between surface/deep learning styles. They recommended that more research was needed to investigate the benefits of this type of approach. Kwok and Jones (1995) describe the benefits of presenting learning based on Pask's surface deep learning style. The use of the Kolb LSI to configure hypermedia presentations has been widely reported (Chou and Lin 1998; Paolucci 1998; Groat and Musson 1995 Rasmussen et al 1998).

In the research presented here, Riding's Verbaliser - Imager (VI) dimension was shown to be effective in configuring the presentation of learning. This may be ascribed to the direct relationship between the way that multimedia is able to present information to learners, and Riding's VI dimension. Despite many examples of the benefits of configuring learning based on Riding's cognitive styles presented earlier in chapter 2 and chapter 5, the VI dimension had not been used in a student model prior to this research.

Evidence for the benefits to the quality of learning provided by the task descriptor in the student model was presented in section 9.3.2.3. Tasks have been shown to be important in learning by many authors. Buckner and Morss (1999), for example, showed that the appropriateness of the task was central to the success of the learning experience in computer-supported collaborative learning. When students were clear about the nature of the task, then benefits included improved motivation, improved learning and ability to assess individual performance in group activities.

The use of task levels as a component of a student model has not been widely reported in the literature. In this research, the differentiation of tasks was found to be important in that it provided a supported yet challenging environment. The benefits of configurable task differentiation to add levels of challenge, was an important finding of this research. It was also found that tasks were valuable in that they provided direct support for group work (see section 9.4.4.1).

Muldner and colleagues (1996) suggest that it is possible to capture some aspects of student learning using a question-based student model. Their model was based on a range of question types. The student model was used to adapt the presentation of instruction according to performance on the questions. The student model presented in this research used questions in a different way. Questions were used, based on the ideas of Felder and Brent (1994), and much in the same way as tasks were used, to impose additional levels of challenge for learners. The benefits of this approach were presented in section 9.3.2.4. Tutors did however express some concern as to the effect on the level of the course of configuring questions at too low a level.

An important finding of the work related to the use of scaffolding as described in section 9.3.2.5, where its effectiveness at providing a supported environment to assist in the performance of tasks was presented. In section 9.4.4.5, scaffolding was related to Vygotsky's zone of proximal development (Vygotsky, 1986) and to Minsky's frames, which were considered to provide structures and tools to help the organisation and integration of new ideas (Minsky 1986). Scaffolding has also been used to support the notion of a cognitive apprenticeship (Collins et al

1989). In a cognitive apprenticeship, an expert agent is employed to provide support which may later be withdrawn or 'faded' (Collins et al 1989). Smith and Jagodzinsk (1995) describe the application of the cognitive apprenticeship idea in a multimedia learning environment for graduate civil engineers, the Cognitive Apprenticeship Model (CAM). Scaffolding was provided by Smith and Jagodzinsk's system, with complex tasks initially performed by the system and later, gradually faded, allowing learners to take on more of the task as their experience grew. Guzdial and Kehoe (1998) also describe similar apprenticeship based learning environments in a hypermedia application.

The cognitive apprenticeship model is an example of a social collaborative approach of the kind recommended by Vygotsky (1986). Hartley (1998) sees a conflict between the individual constructivist approach to learning, with the reduced role of the tutor (Piaget 1985) and the social collaborative approach recommended by Vygotsky (1986), where the emphasis is placed on learner - tutor collaboration. The effectiveness of scaffolding used as a component of the student model in this research is explained in part by the marriage of these two ideas into a single system. The benefits of providing scaffolding to help present and explain ideas are to be had without the loss of an individually constructed learning environment provided by the task-based approach.

10.2.4.3 The collaborative student model

Cummings (1998) states that individualism is a key goal in education and that this must inevitably rely on learner modelling. The contrast between the diverse but sketchy learner models that human experts use in the classroom, and the concern of AI modelers to provide complete models for use in computer systems is emphasised by Cummings. In this research, a simple student model was developed that contained information that could be used to configure learning for each individual. This model, despite its outward simplicity, held important information that was used by human experts in co-operation with the computer to configure learning effectively.

The learning-decision making process provided in this way was in some respects similar to the types of learning decisions made in classrooms and in one-to-one sessions with learners and tutors. In this way, the student model was able to configure a multimedia presentation optimally for each learner, yet still provide features important in human to human interactions that take place in learning. Indeed it is argued that the student model presented here was able to hold and act upon a great deal more useful information about individual learners than would be possible in classroom situations. Learning was individualised and optimised by a collaboration between tutors, learners and computers. This research described in this thesis presented the benefits of this approach. It was found that the *simplicity* of the student model employed, was itself important and that this simplicity contributed to its pedagogical power (Ohlsson, 1993) as it allowed tutors to interact with the model more effectively. The lack of Ohlsson's micro-decision points in the implementation of the model, far from being a disadvantage of the global descriptor approach, was one of its strong features as described in section 9.3.4. Pedagogical power was placed in the hands of tutors and not under the control of computers.

10.2.4.4 The development of meta-level skills

In a cognitive apprenticeship, movement from novice to expert involves gaining metal-level skills (Cummings, 1993). Cummings describes the de-coupling of task level and discussion level interactions in computer applications as important in the movement from apprentice to expert. Guzdial and Kehoe (1998) describe 'conceptual' and 'process' knowledge in their hypermedia system. Mcintyre (1993) suggests a distinction between domain knowledge (what to teach), and strategic knowledge (how to teach). These authors express similar ideas about the importance of meta-level skills in teaching and learning.

In the research presented in this thesis, the development of such meta-level skills was supported on the one hand by discussion with human experts, either in group work or with tutors, and on the other by the provision of a supported task based environment which provided challenge and support at an individual level.

10.2.4.5 Summary of the student model

In summary, the use of a co-operative student model based on a global description of learners was effective in providing a high quality learning environment, based upon constructivist ideas of learning. It was found that this approach made the best use of computers to present information optimally and of human intelligence to control the complex learning decisions.

10.2.5 Multimedia and learning

The multimedia materials developed in this research were shown to be high quality and usable. It was argued in section 9.4 that this had a great influence on the quality of learning. It was a consistent feature of almost all the evaluations presented in chapter 8, that the high-quality screen design and usability features of the application were cited as important features in their use. Experts rated these features highly as achieving their stated objectives in the areas of usability, screen design and in the area of instructional design. This was important because tutors and students were then prepared to invest effort into materials that were well-designed and well-presented. It was also important to tutors that consideration was being paid to learning, rather than to the development of a system to replace teaching.

Evidence was provided in chapter 8 that using the learning materials caused changes in some tutors' attitudes to the use of multimedia, especially the use of student modelling in multimedia. It was important that the design of the materials was such that all stakeholders were aware that these were learning materials not instructional materials. They were related directly to assessment and provided a high level of support for the gathering of evidence necessary to obtain real qualification. This tool was important not just for learners, but also for tutors. Task-based, assessment-driven materials that provided tools for gathering evidence to prove competence were valued by tutors and students.

The importance of a constructivist approach to learning was reflected in the design of the multimedia. There was evidence, presented in section 9.4, that the materials did reflect a constructivist approach to learning. The use of instruction and construction in multimedia applications is summarised by Atkins (1993), who suggests that both have their place in the design of multimedia. Atkins' view was not fully supported in this research. Presentation-based applications developed according to behaviourist, instructivist guidelines were consistently rated lower than those based upon constructivist principles in the exploratory studies described in chapter 3. The idea of using a task-based approach to multimedia with task and question level differentiation was found to be sound and to be in line with a constructivist view of learning. Carrol (1990) has stated that learners require real interaction with real tasks rather than formal drill and instruction exercises. Carrol's view was supported in this study, by the attitude of tutors and students to the materials.

The importance of pedagogical structure in multimedia learning materials has been identified by several authors (Boyle 1997; Laurillard 1993; Richards 1996; Jonassen and Hannum 1987). Laurillard (1993) criticises the resource based approach to learning and suggests that the responsibility for structuring learning should fall upon the multimedia designer. Henderson (1995) states that a limitation of resource-based web and CD-ROM delivered learning is the requirement to rely upon the local tutor to provide structure. Henderson suggests that highly structured learning environments be provided to overcome this limitation.

Rather than adopt Henderson's suggestion it was found that by involving tutors in all stages of the project, not only was Henderson's objection overcome, but there were also additional benefits to be had, not least in providing motivation for tutors.

10.2.6 Management of learning

Evidence was provided for the importance of the management of learning in the quality of learning. The tutor and the learning environment were shown to be important in this process and there was evidence (presented in section 9.5) that when there was a mismatch between the objectives of the different stakeholders, the quality of learning suffered, irrespective of the quality of learning materials in use. Where there was a sharing of objectives, learning quality was likely to be high.

The local learning environment, the microenvironment, had an important influence on the quality of learning. The microenvironment was established by the tutor and the learners, and also depended on the facilities provided by the institution, including classrooms, hardware, software and a range of support. The microenvironment was the location where all the factors involved in the quality of learning, including the student, the tutor, the influences of the macroenvironment and the learning materials were brought together. Evidence for the complexities of the relationships between these factors was presented and some causal relationships between students' attitudes, tutors' attitudes and the quality of learning were shown. The importance of this in the evaluation process will be considered later, where ideas for an evaluation framework are discussed.

10.2.7 Summary

In summary, the co-operative student model, used in a rich, differentiated, task-based multimedia learning environment was shown to have a positive influence on the quality of learning. In the next section, the role played by the Grounded Theory research methodology in the study is discussed.

10.3 An evaluation of the Grounded Theory methodology

In chapter 6, a comparison of qualitative and quantitative research methods was presented. It was argued there, that an empirical scientific method such as employed in the experimental work presented in chapters 4 and 5 was inappropriate for the evaluation of a highly complex system required in the final study of this work. Qualitative methods of analysis are often employed in circumstances involving multiple variables and complex relationships, such as in the conditions that were present in the final study. It was impossible to impose the kinds of controls over these conditions that would be necessary in a scientific experiment. For these and other reasons presented in chapter 6, a qualitative research approach was employed in the final study.

Before the final study, a range of qualitative research methods was investigated. These included, Case Studies, Participant Observation, Phenomenology, Ethnomethodology and Grounded Theory. Of these methods, a Case Study or Grounded Theory approach was most appropriate for the study, given the skills available and the circumstances of the final study, especially the requirement for a fairly short study taking place at six locations. Of these two alternatives, the Grounded Theory approach presented a single, unified, systematic method of analysis that was less apparent in the Case Study method, which seemed to rely very much on individual methods and systems. This would make the application and interpretation of Case Study methods more difficult, especially in consideration of the requirement for remote management and data collection. Grounded theory was able to integrate well with quantitative methods (Strauss and Corbin 1991). It has also been claimed that Grounded Theory employs a rigorous methodology based on the canons of scientific research (Scott 1996). From a personal viewpoint, the Grounded Theory methodology was well established and documented (Strauss and Corbin 1991; Denzin and Lincoln 1994; Glaser and Strauss 1967). This made it possible to acquire and apply the necessary skills to the research question. The Grounded Theory method was therefore selected as the qualitative research method for the final study. In the rest of this section, an appraisal of the effectiveness of the Grounded Theory research methodology employed in the final study of this thesis is presented.

A major benefit of the Grounded Theory approach was the requirement to undertake a preliminary analysis, referred to as the Open and Axial coding stage of the method. In this stage, a great deal of evidence related to the research question was gathered from a range of sources. This process is described in chapter 7 of this work. The organisation of these data into a coherent structure was vital to understanding the complexities of the research question. In a process which took many months, issues were organised, clarified and related in categories and sub-categories. The tentative structure arrived at iteratively during this process was important in organising and clarifying the many inter-related issues in the complex problem. This clarity was important in planning the evaluations that were undertaken in the final study and also in the interpretation of the results.

The fact that the study was based upon a documented structure was also important in providing an understanding of the research issues to others involved in the project. For example it was possible to discuss problems with designers who could immediately understand objectives and ideas behind their work. The fact that a documented structure to the problem existed provided other benefits, for example many of the assumptions inherent in the study were made clear by the structure. This would be likely to provide help for those wishing to repeat the work in the future.

The Selective coding stage of the research involved the selection of the core category around which the research phenomenon could be understood. This involved relating subsidiary categories to the core category using the paradigm model, relating categories at the dimensional level (the variables identified in open coding) and the validation of relationships against data obtained. The 'quality of learning' presented itself as the core category as it was found to be directly associated with all other categories involved in the phenomenon. It was now possible to relate other categories to this category, using the techniques of Grounded Theory. 'Grounding the theory' was accomplished by finding and describing causal relationships that were consistently present in the results obtained and relating these to the quality of learning. In this way an understanding of the phenomenon emerged from the study. The end of the study was achieved by the presentation of a rich narrative relating the research phenomenon to the data.

The Grounded Theory method was effective in understanding the research. Once a structure for the study had been arrived at, it was possible to look for specific and consistent relationships between categories based upon data obtained. In this way the most important relationships presented themselves. In a rich and complex phenomenon under study with limited resources it was important to direct effort towards the most promising relationships. Grounded Theory helped in this by providing a structure which could be tested by data.

It was also true that theory and new understanding arose for the study, due to a large extent to the research method itself. For example the relationship between tutors' attitudes to student modelling and tutors' previous experience of the AI approach to ILT was completely unexpected prior to the study. By contrast, in the application of scientific method, theory is generated prior to research and is tested in experiment. In this study, theory about the relationships between the data and the phenomenon consistently presented itself from the study and was able to be integrated into the narrative, producing new ideas, important in the iterative process of developing theory. The structure of categories and sub-categories provided a framework around which data could be presented and understood. In this way the complex phenomenon was organised and understood.

In order to perform a Grounded Theory study, there was a considerable overhead in terms of time and effort. The development of new techniques, the requirement for a preliminary study and the need to develop theory systematically all added to the difficulties inherent in performing the final study. However it is argued that a Case Study approach would have been unlikely to provide the richness of a Grounded Theory study and that in the longer term a greater understanding of the phenomenon was possible due to the approach adopted. In adopting a Grounded Theory approach it was intended to undertake research in a complex area of study, using the most promising method. It was not an objective of the study to develop or evaluate the Grounded Theory research method in this particular context. It was inevitable however that this took place to some extent. The effectiveness of any research method ultimately depends upon what it can deliver. It is argued here that the results obtained could not have been obtained by any other available approach.

Hammersley (1992) suggests that the results of qualitative research may be interpreted in terms of its own internal logic and validity and that it is more difficult to relate such results to aspects of the 'real world'. In the rapidly changing worlds of education and ILT, this was not seen as a negative aspect inherent in the method employed. An understanding of such a complex phenomenon as studied here is very dependent on context. An important feature of the study was an understanding of the influence of context. The development of an understanding of cause, effect and context was an important result for this investigation. The implications for this in the evaluation process will be discussed more fully later.

It was possible, then, despite Hammersley's objections, to make generalisations about the quality of learning and the use of individually configurable multimedia investigated in this work. The ability to make such generalisations was important in understanding the many influences on the stakeholders during the study. These were likely to have a wide influence in many locations. The fact that there were many similarities between the findings at different locations supported the view that generalisations could be made.

Major influences on the quality of learning were the learning materials, the student model approach and the management of the education process. These comprised a complex mixture of specific as well as general influences and effects. It is argued that in the approach adopted, some of this complexity inherent in the phenomenon was made plain. The aim of the final study was to develop a multimedia application based on a student model which could be configured according to learners' individual needs. An investigation to answer the principal question, *'has the multimedia application configured in this way been beneficial to users in the delivery of effective learning?'* was performed and the Grounded Theory approach employed was effective in satisfying this aim.

Experimental methods, though powerful, are artificial and limited in the number of variables they examine at any one time. Grounded Theory was able to examine the complex processes and mechanisms involved in the study in a real setting involving very many variables. An important limitation of the Grounded Theory approach are that there is less certainty in terms of the generality and causal relationships inherent in the findings.

10.4 A framework for evaluation

An important finding of the investigation was the importance of evaluating learning materials in a full context. It has been argued that it is difficult, if not impossible to evaluate learning materials without this requirement (Squires and McDougall 1997). There was a evidence from the investigation in support of this idea, especially in the preliminary stages of the study reported in sections 7.3.1 and 7.3.2. It became clear that the overall objectives of the stakeholders in the learning process were not always shared or even mutually understood. This was especially true with the objectives of the tutors and those of the educational system. Evidence for this was presented in chapter 9 of this work. Even when general objectives were shared between stakeholders, there was evidence that specific objectives relating to the direct use of the learning materials were not always the same. Sosabowski and colleagues identified factors important in overcoming resistance to computer-based learning (CBL). In addition to training and access to resources, they suggest that staff attitude is a major factor in resistance to CBL (Sosabowski et al 1998).

If a more limited study had been undertaken, which concentrated on learners in isolation, issues related to the role of tutors and the educational system in the learning process may not have been identified. As a result, it would not have been possible to obtain insights into many of the factors related to tutors, the educational systems and their influence on the quality of learning. The findings of this thesis support the view that tutors are central to the establishment of the quality of learning taking place. This issue is crucial in defining the evaluation context and is discussed in the rest of this section.

As stated above, the evaluation of learning materials is best situated in a context according to Squires and McDougall (1997). The context they identify in their Perspectives Interaction Paradigm (PIP) was found to be particularly useful in designing evaluation objectives for the final study. In their approach, the authors discuss ways to use different perspectives in order to understand teachers', students' and designers' perspectives in formative evaluation to guide the development of learning materials, and to perform predictive evaluation as to their situated use. They suggest that by adopting the different perspectives of the stakeholders, the PIP approach allows a holistic, situated approach to the evaluation of software in context.

Draper (1997) suggests that there are many influences on the evaluation of CAL. Notably, the action of teachers may influence performance and the way that software is used will influence evaluation (Draper 1997). Pollock et al emphasise the need to include the teacher in evaluation in their report of the conversion of a mathematics course to CAL (Pollock et al, 1996). Brown et al found that by using an integrative approach to evaluation, employing a range of evaluation methods in real learning contexts, it was possible to help teachers make better use of CAL, rather than merely informing software choice decisions. Integrative evaluation is an attempt to improve teaching and learning by the 'better integration of CAL material into the overall situation' (Brown et al, 1996). The importance of this approach was upheld by the findings reported in this thesis. The involvement off all the stakeholders in the process was found to be essential not only in effective evaluation, but in the use of the software and in the ultimate quality of the learning its use provided.

Gunn (1997) describes the development and application of a Situated Evaluation of CAL (SECAL) framework which was used to guide the evaluation of a CAL course in human anatomy in an HE environment. This model was able to produce meaningful results, despite the limitations imposed by the need to include the CAL component as a fully integrated part of a course. These ideas are supported by the findings of this research. The complexity of the relationships that conspired to influence the quality of learning were such that evaluation in the absence of a framework would be meaningless. In the study reported here, the framework for evaluation was provided by the evaluation methodology which constructed the evaluation system specifically for use in the study. It was clear from the study that it would be important in future work to provide a framework in order that evaluation could take place routinely in full context. Evaluation of software is an important procedure which is required to take place regularly.

The situated approach of Squires and McDougall was recommended to be used in a formative way to develop CAL software and in a predictive way to assess the potential of software for a specific purpose. Quite often however, software is assessed in situations where objectives are not clear, guidelines for use are not present and the staff and students involved are not sure what is required of them. This was evident from the study undertaken. In such circumstances, evaluation is likely to be negative. The application of a system similar to the SECAL system suitable for application in a FE environment and capable of ready application to the formative and summative evaluation of CAL software will be important.

It is further suggested that any system intended to clarify the evaluation objectives of each of the stakeholders could also serve another purpose, that of communicating objectives. From the study, there was evidence that where objectives were understood and shared between stakeholders, then the quality of learning improved. Thus not only was the general sharing of objectives important in the evaluation of CAL, it was also important in learning with CAL. This being the case it is argued that an evaluation system should have the communication and sharing of objectives as a major aim. In such a system, the approach of Squires and McDougall might be integrated with an approach similar to Gunn's SECAL method in conjunction with a communication and training package to specify and clarify a range of issues related to the interests of all stakeholders.

The evaluation of open and flexible learning materials is an important issue in FE at this time according to Lockitt (1999). It is performed by a range of practitioners for many reasons, including as a justification for resource allocation. Evaluation is costly and usually it is not done well. A framework for evaluation would clarify issues and not only allow evaluation to take place efficiently, effectively and in a directed way, it would also require objectives to be stated explicitly and be shared among all stakeholders.

10.5 Future directions for research

The thesis presented here covers many aspects of learning with and through the application of technology. It was possible to show within this research programme how several factors were important in learning and to understand some of the relationships between them. Due to limitations of time and the need to focus on the research objectives, it was not possible to follow all the interesting avenues that presented themselves within the study. In the next section, some of these factors are discussed and the potential of this project to motivate future research is evaluated.

10.5.1 Student modelling and multimedia

Important findings of this research were that the application of AI methods did not preclude a constructivist approach to learning and also that there were benefits to be had from the student modelling approach. For these reasons it is likely that there is great potential for the use of a student model in multimedia. It was difficult to decide upon the final form of the global descriptors used in the study. Tasks, questions, cognitive style, language and scaffolding level were selected because of their perceived importance from theoretical considerations and from the results of exploratory studies. It would be important to consider the potential of other global descriptors in order to develop a fuller description of the characteristics of individual learners within a student model.

The potential of new descriptors needs to be explored, for example the use of other cognitive and learning styles dimensions has been discussed by several authors (Clarke 1993; Fitzgerald 1997; Jones et al 1997; Kwok and Jones 1995; Liu and Reed 1994). It would be interesting to use these and similar descriptors in future work.

It would also be important to consider the potential of learning strategy as a descriptor in the student model. Learning strategies are employed by learners in response to learning situations in an attempt to overcome problems and engage in learning. The potential of developing learning strategies by including them in a learner model is interesting. It may be possible, with a knowledge of what strategies learners were using, to influence the development of a wider range of strategies in problem solving. It may thus be possible to produce a more balanced range of strategies available to a learner or perhaps to influence the selection of strategy by a learner in different problem solving situations. The use of learning strategies in such a structured way might not only assist in the delivery of learning, but also improve basic skills in a learner. A student model might hold information about the skills a learner possessed in particular areas and any deficiencies. It might make recommendations useful in the development of new strategies or in the use of existing ones in a given situation. Example of learning strategies that might usefully be employed are the Kolb Learning Styles Inventory (Kolb and Fry 1975) and the Surface -Deep dimensions (Pask 1976; Entwistle 1981).

It would also be important to look at Riding's (1991a) Wholist - Analyst cognitive style dimension to understand the potential for configuring the presentation of multimedia based upon this dimension. The potential for organising information either as a whole and supporting the understanding of its detail, or in detail and integrating its overall meaning presents an exciting application of Riding's work, eminently suited to the use of a student model and multimedia. It is intended to develop new multimedia tests for a range of cognitive and learning styles in the future to support this work.

The importance of language in the student model emerged strongly from the research undertaken in this study. The potential of tailoring language specifically to each learners' needs was developed in this work and found to be effective in aiding learning. There is also great potential for using multimedia systems not only to support language, but also to challenge and develop linguistic skills. By using language and a system of differentiated scaffolding together it would be possible to support deficiencies in linguistic skills and at the same time to extend each learners' zone of proximal development (Somekh 1996) in order to develop new skills. The organisation for such a complex task could be managed by the use of a student model.

The use of a co-operative student model provided great benefit to the stakeholders. It would be possible in further work to develop these methods and understand their influence more fully by means of a longitudinal study. The development of tools to help in the efficient establishment and configuration of the student model by tutors would be an important objective of the study. A major problem identified in this work with the co-operative approach was the amount of time the process took.

Finally, group working in a task-based environment is another positive aspect to emerge from this study which might benefit from a fuller study either as part of a student model or as a study in its own right. Methods of incorporating the positive aspects of tasks, questions and group working into educational technology will be important in the future as ILT becomes more of a group activity.

An important point discussed earlier, in section 10.4, is the development of an evaluation framework, including a system for the communication of objectives. It is likely that the need for such a framework will change as the objectives of the educational system evolve with the development of new technology and the acceptance of existing technology. It is unlikely for instance, that the provision of computer hardware support will be a major issue for long into the future. The provision of high-quality support will become an axiom of ILT support within all institutions and other issues will become more problematic. It will be important to monitor, record and understand these processes of change, so that the evaluation of new systems can be accomplished effectively in the context of shared objectives between stakeholders.

10.5.2 Practical application of this work

The research reported here has had important practical application in colleges of FE. The methods developed within this project have been applied widely by materials developers and ILT practitioners in twenty-one colleges in the UK. Ten multimedia applications have been developed based upon the use of the student model reported here and ten more are currently being produced. Although it was not possible to use all features of the student model in applications, this is an objective for future work. An evaluation framework has been developed based upon ideas reported here and is currently being implemented in pilot locations. Models of implementing high quality multimedia learning materials into the curriculum have been developed in a range of educational contexts for use in the future (Anderson et al 1998), and these will provide a basis for further practical applications of the work described in this thesis.

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