Facilitating Teaching and Learning of Programming with Interactive Multimedia

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ABSTRACT

This thesis investigates effective ways of designing and integrating Interactive Multimedia (IMM) to facilitate teaching and learning of programming. Drawing on a preliminary investigation in IMM and learning, an initial design and integration approach was developed. The architecture and design features of IMM courseware and its integration were modelled to support the learning activities defined by Laurillard's conversational and Mayes' learning frameworks and to accommodate the needs for the domain identified at two UK Universities. The approach aimed to improve the quality of student learning with IMM courseware through creating a learning context which supports the teaching and learning processes; encourages students to use the courseware for learning; and increases their motivation and interests in the subject matter they study. The primary emphasis of this approach lies in integrating IMM for lectures and tutorial.

Sequent case studies were conducted to evaluate the effectiveness of the approach in supporting teaching and learning. Two IMM courseware, consisting of resource-oriented and task-oriented materials, were developed and integrated into four programming modules at Napier and Brunel Universities. To explore the effects of hyperlinks in problem-solving contexts, three different variations of the task-oriented material were developed: one without hyperlinks, the second with questions (*static*), and the third with model answers when the questions were answered incorrectly (*dynamic*).

The results suggested that student learning experience was enhanced by the use of the IMM courseware for teaching and learning: their performance and perceptions of the subject matters improved. Using the IMM courseware in lectures and tutorials enhanced the teaching and learning processes, promoted active learning and reflective thinking, and created collaborative learning environment. However, weaknesses were also identified in supporting student learning with different knowledge levels. As for the hyperlinks effects, the results showed that the 'dynamic' hyperlinks improved students' performance most effectively. They helped students become aware of their misconceptions and correct them through revisiting the resource-oriented material; and in the process reflect on what they learnt in lectures. The 'static' hyperlinks were found to be beneficial when students did not have sufficient knowledge to test. In addition, the results revealed various factors affecting student learning with IMM. Among them was students' familiarity with IMM, which emphasised the importance of integrating IMM courseware in a way that encourages students to use it for learning.

The thesis presents a design and integration approach informed by the findings from the case studies, and proposes a design and integration process with IMM. The process consists of three phases (designing and integrating IMM, and facilitating learning with IMM) and the factors affecting the phases, and illustrates the relationship between them.

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CHAPTER 1 INTRODUCTION

This thesis argues that a full integration of Interactive Multimedia (IMM) courseware for both teaching and learning can improve the quality of student learning of programming. As a means to facilitate student learning, this thesis presents an approach for the design and integration of IMM courseware. This approach is developed from theoretical review in pedagogy and IMM, and the empirical findings from the empirical study of investigating teaching and learning with IMM courseware which were used for both lectures and tutorials for programming modules. This thesis reports the findings from the empirical study and discusses how the approach can support teaching and learning processes of programming. In addition, it discusses factors affecting student learning with IMM courseware and the importance of creating an environment in which students are encouraged to use it for learning.

1.1. Research motivations

To facilitate learning with interactive multimedia

Educational multimedia packages are on the fast increase, as fast changing technologies offer a possibility for higher education to facilitate learning for the increasing number and diversity of students. Although they are expected to promote deep learning through using multimedia and grounded in sound pedagogy, many packages have disappointed users with their quality and educational value (Laurillard, 2002; Aldrich et al., 1998). One reason is that some multimedia materials have been poorly constructed, paying lip service to supporting the learning process (Rogers & Scaife, 1997). Presenting dynamic media may attract the user but does not always promote 'deep' learning. If educational multimedia is to live up to its expectations and have a genuine pedagogical value, then much more focus is needed on how to support the cognitive process by and with an IMM courseware in the learning context (Rogers & Scaife, 1997). IMM courseware must be designed and integrated in a way that learning activities and interactions required for learning can be fully facilitated in the learning context.

The inadequate integration of IMM courseware into its learning context often results in consequent neglect of the courseware, rather than finding their proper place or changing the context to facilitate their use (Laurillard, 2002; Laurillard, 1997; Soper, 1997). In order to facilitate student learning with IMM learning materials, first of all, we need to facilitate the use of IMM materials to fully benefit from them in the context, and it should start from understanding how students experience learning with IMM from their perspective. Unless it is used, little value of IMM courseware will be realised. Creating a learning environment in which students can be encouraged to use IMM courseware is essential to facilitate student learning with IMM. This thesis argues that using IMM in lectures and tutorials can encourage students to use IMM courseware for learning. It would be particularly suitable for programming courses, as curriculum activities of these courses include theoretical studies in lectures and practical work with computers in tutorials. This creates a natural environment in which IMM courseware can be integrated seamlessly without altering major teaching and learning activities. Using IMM courseware can also integrate theoretical aspects of programming and practical work together. This can help students adopt a 'deep' approach to learning.

Another reason that many IMM materials have not met expectation is that much time and efforts are invested on designing and developing IMM materials, and relatively little on evaluation (Laurillard, 2002). As a result, there are relatively insufficient empirical findings on IMM courseware in supporting learning. A long term evaluation in how student experience learning with IMM courseware in natural teaching and learning environments can inform how we should facilitate teaching and learning with it.

Difficulties in teaching and learning of programming and the potential of IMM

Teaching introductory programming can be a challenge. Difficulties lecturers encounter can be classified into three main categories: the diversity of students' background knowledge and interests in the subject matter; students' 'surface' approaches to programming; and the dynamic and abstract nature of programming. All these three can be and often are experienced in teaching programming modules. Computing is a well-structured domain, and in a well-structured domain, knowledge is hierarchically structured. An understanding of new concepts is often only possible if the previous stages have been fully grasped (Prosser & Trigwell, 1999). Students in introductory programming modules are often from different courses, and their interests, background knowledge and motivations vary. It can be particularly challenging to create a learning environment in which these students can be encouraged to adopt a 'deep' approach to learning.

To facilitate students' learning with programming, various teaching strategies and tools have been used. For example, to manage the diversity of students, Davis et al. (2001), and Jenkins and Davy (2000) used differentiated teaching strategies based on students' background knowledge. Others used problem-based learning or problem-based teaching to help students approach the programming processes holistically (i.e. Barg et al., 2000). One most often used and powerful method is visualisation. Tools such as JBuilder and Visual Basic are commonly used to support students' understanding of the programming processes through providing visual aids for software development. There are other special tools such as TeacUP graphically illustrating the dynamic execution of a programme (Linington & Dixon, 2001), and Alice98 visualising the recursive execution process (Dann et al., 2001). In addition, Shinners-Kennedy (1995) used Microsoft Excel to teach object-oriented concepts.

IMM has a potential to support student learning of programming with its dynamic media, i.e. visualisation, and interactivity. As mentioned above, the learning activities in programming domains consist of theoretical studies in lectures and practical programming work in computer labs. Students tend to focus on programming part of tasks (coding) in tutorials. Tasks in IMM courseware supporting student learning of programming concepts and linking them with practical design and programming work can encourage students to approach the programming processes holistically.

1.2. Research questions

This thesis aims to evaluate the effectiveness of the design and integration approach through answering the five research questions.

How does using IMM courseware in lectures and tutorials support teaching and learning processes of programming? (What are the benefits of using IMM courseware in lectures and tutorials?)

In order to facilitate learning with multimedia, not only do we need good educational materials but also to use them in a way that enables students to learn from them. Soper (1997) emphasises that:

> 'Multimedia learning materials address students' learning needs in a variety of ways and offer students involvement in and control over their learning process, while possibly also enabling larger class sizes to be taught. Effective use of these new materials requires, however, that they be integrated with the rest of the course and that students have appropriate support and guidance in their use.'

The empirical study aims to evaluate how effectively using IMM courseware in lectures and tutorials can facilitate student learning of programming.

What factors affect student learning with IMM courseware, when it is integrated into courses for both teaching and learning?

In order to improve teaching and learning, it needs to start from understanding how students experience learning from their perspectives and then to create an environment which affords a 'deep' approach to learning (Ramsden, 1992). Studies in student learning have identified various factors affecting students' approaches to learning such as their prior learning experience, learning context and etc. In the same way understanding what affects students' approaches to learning with IMM is essential in order to improve student learning with it. The empirical study conducted in teaching and learning environments can inform how student experience learning with IMM courseware and what factors affect their learning with it.

How do hyperlinks as part of feedback in problem solving contexts support the learning process?

Questions provide a means of stimulating recall and testing understanding. It also provides an incentive to try to accomplish the task (Soper, 1997). In addition, questions with intrinsic and extrinsic feedback can support the 'goal-action-feedback' cycle (Laurillard, 2002), which is an essential aspect of learning. A question is if students can visit related information that they were already exposed to in lectures, how effectively can it support learning? Can it encourage them to learn more actively?

The architecture of IMM courseware, this thesis proposes, consists of a resource-oriented material (targeted for lectures) and a task-oriented material (for tutorials). As part of feedback hyperlinks as a means for direct access to related information in the resource-oriented material are embedded. To explore an effective way to provide feedback with hyperlinks, the empirical study tests three different variations of hyperlinks treatment: no hyperlink between the two materials, the second provided with questions and the third with the model answer after students answered a question. The results from the case studies will inform the learning effects of hyperlinks as part of feedback for learning, and what types of hyperlinks can support student learning of programming most effectively.

How effective is visualisation in supporting teaching and learning of programming?

Visualisation is one of the most popular methods used to support student learning in programming domains. Most design and programming tools, such as JBuilder and Visual Basic, provide graphical interface to support students' understanding of the programming processes. How about using visualisation illustrating programming concepts with real life objects? Can it help students' understanding of programming concepts? Another question is that if animations illustrate programming concepts in the design and programming processes, can it help students approach the programming processes holistically?

IMM courseware, this thesis proposes, uses visualisation as one of main features in the resource-oriented material. How much visualisation in IMM courseware helps students' understanding in lectures and for learning can be interesting to investigate.

Can using IMM courseware in tutorials promote interactions between the tutor and students, and between students?

'Dialogue' is one of the most important factors influencing the learning process (Ramsden, 1992; Mayes, 1997; Laurillard, 1993). Creating a collaborative environment is important in order to facilitate student learning. Can integrating IMM courseware into tutorials improve interactions between the tutor and students? Or will it isolate student learning experience? Investigation will focus on answering how effectively IMM courseware can facilitate the tutor-students interactions in lab sessions as well as students' interactions with the IMM courseware.

1.3. Structure of this thesis

The framework used for this research is illustrated in Figure 1-1.

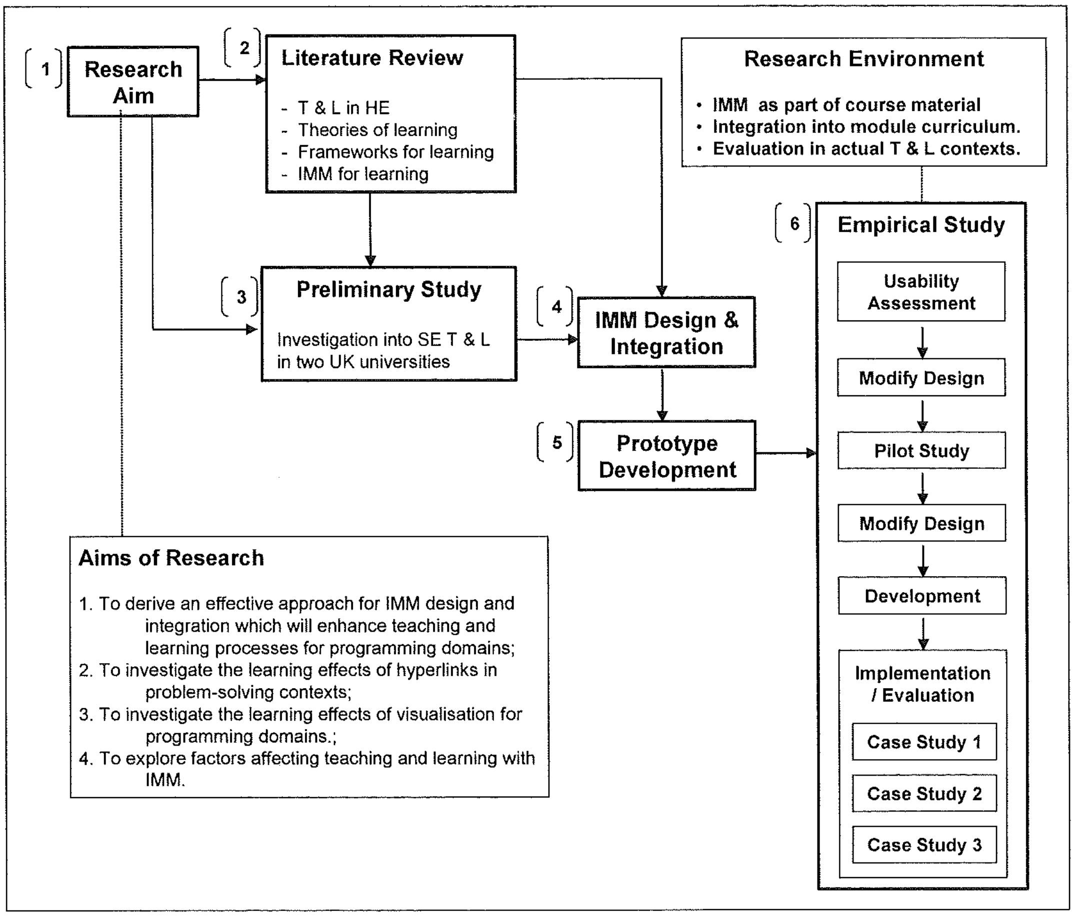


Figure 1-1 Research framework

Following the brief introduction above, the next chapter reviews background literature relevant to the research. Four main fields appear most relevant, as shown by the research framework in Figure 1-1: teaching and learning in higher education, theories of learning, frameworks for learning and IMM. Chapter 2 begins by exploring how students experience learning, and the relationship between teaching and learning to explore the role IMM courseware could play to enhance the teaching and learning processes. This chapter continues to explore psychological aspects of learning, and frameworks that illustrate the learning process and define the learning activities and interactions required for learning. This chapter then turns to explore the potential of IMM for learning.

Chapter 3 reports a preliminary study that investigated teaching and learning of introductory programming modules at two UK Universities. This study aimed to identify the difficulties of teaching the domains, and to explore how IMM can be brought in to improve the quality of student learning. Based on the theoretical review in Chapter 2 and the findings from the preliminary study in Chapter 3, Chapter 4 proposes a way to facilitate student learning of programming, which is through supporting both teaching and learning with IMM courseware.

Chapter 5 reports a pilot study conducted to assess the usability and learning effects of IMM courseware developed based on the IMM courseware design guidelines presented in Chapter 4. With the findings from the pilot study, IMM courseware was modified and further developed. Chapter 6, 7 and 8 report three case studies conducted to investigate students' learning experience facilitated by the integration of IMM courseware for teaching and learning. Chapter 6 reports case study 1 at Napier University conducted to investigate group learning support by the use of IMM OO in lectures and tutorials, and to evaluate the learning effects of three hyperlinks treatments. Chapter 7 reports case study 2 at Brunel University, which focused on exploring individual student learning experience with IMM courseware. Chapter 8 reports case study 3 at Brunel University investigating the benefits of IMM courseware for teaching and learning from the lecturer's perspective.

Chapter 9 summarises the main findings from the studies. This chapter discusses students' learning experience with IMM courseware and how the integration approach supported teaching and learning of programming. Contributions will be offering a way to facilitate learning, particularly for programming domains, with IMM, and adding new findings to how students experience learning with IMM and what affects their approaches to using IMM for learning. This chapter closes with proposing a modified integration approach with IMM based on the empirical findings, and future work.

CHAPTER 2 LEARNING AND INTERACTIVE MULTIMEDIA (IMM)

This study, reported in this thesis, aims to find an effective way to facilitate student learning of programming with IMM courseware in higher education. This requires, first of all, a good understanding of how students experience learning in higher education (Section 2.1). Learners construct knowledge through interacting with the world in which they are engaged in learning. In terms of student learning in higher education, the world would be their learning environment in which teaching and learning takes place. The learning context affects how and what student learn. Therefore, to order to facilitate student learning with IMM, it should start from understanding the learning and teaching processes in the learning context. At the end of the review, implications for the design and integration of IMM courseware will be briefly discussed.

In addition to understanding how students experience learning in higher education, IMM courseware design and integration for learning should consider psychological aspects of learning. Having reviewed literature in theories of learning, their implications for IMM courseware design and integration will be discussed (Section 2.2). Frameworks for learning are reviewed to identify interactions and learning activities IMM courseware needs to support in the learning context (Section 2.3). The potential of IMM for learning is discussed in Section 2.4.

2.1. Learning and teaching in higher education

In recent years higher education has faced significant changes which have required it to transform itself in many areas to accommodate those changes. One area in which most significant changes are required is teaching and learning practice. The changes that concern teaching and learning practice are the rapid increase in the number and diversity of students entering higher education, a growth and a change in subject matters, and advances in learning theories and technologies (Light & Cox, 2001; Ramsden, 1992; Laurillard, 2002).

The vast increase in available information and the rapidity of information updated resulted by social change and technological advance necessitate changes in both teaching and learning. In terms of student learning an emphasis on mastering domain knowledge has shifted to acquiring problem solving, communication and team working skills within a multidisciplinary problem-solving context. Learning is seen not simply as products but as a series of activities, and developing skills and capabilities as much as formal knowledge. The focus of teaching has become from imparting knowledge to facilitating student learning (Laurillard, 2002). This perspective has changed the roles of the teacher and the student. The teacher, rather than the student, has become responsible for what the student learns and how they learn (Laurillard, 2002; Prosser & Trigwell, 1999; Ramsden, 1992). Ramsden (1992) emphasises this asserting: 'The aim of teaching is simple: it is to make student learning possible' (p5). Laurillard (2002) defines 'creating the conditions in which understanding is possible' as the teacher's responsibility and 'taking advantages of that' as the student's responsibility (p1).

It is important to create a learning context which affords a meaningful learning and in which students are encouraged to perceive it affords a 'deep' learning approach. To achieve this requires an understanding of student learning from the student's perspectives and its relation to teaching (i.e. Laurillard, 2002; Prosser & Trigwell, 1999). Extensive studies in student learning from the student's perspectives have brought findings in terms of differences in student learning outcomes, their approaches to learning and factors affecting their learning (i.e. Laurillard, 2002; Prosser & Trigwell, 1999; Marton & Booth, 1997; Marton et al., 1997; Ramsden, 1992; Gibbs, 1992; Entwistle et al., 1992).

2.1.1. Approaches to learning

In '*Learning and awareness*', Marton and Booth (1997) put a question: 'why do some people learn better than others?' Studies in student learning have found qualitative differences in student learning outcomes in the areas of general intellectual level and content-related outcomes, i.e. critical thinking, interpersonal and problem-solving skills (i.e. Prosser & Trigwell, 1999; Marton & Booth, 1997; Ramsden, 1992). In the same context students experience learning differently not only in what they learn but also in how they learn.

Marton and Saljo (1984)'s study in students' reading academic texts found variations in the quality of student learning outcomes. Students approached the reading texts with different intentions and this resulted in variations in their learning outcomes. Marton and Saljo classified them into two categories, and each category had two related aspects in terms of 'what' and 'how' students approached to the reading task. In terms of 'what', there was a clear difference between students who sought 'meaning' and thus understood the text as the author intended and others who focused on the text itself and as a result accomplished only a partial or no understanding of the text: a *deep* and a *surface* approach. The intention of the students who took a 'deep' approach was to understand the text and they focused on understanding the 'meaning' seeking what was 'signified'. The students who adopted a 'surface' approach focused on the text itself, paying attention to 'signs' in the text and missing the message it tried to convey.

In terms of 'how' part, some maintained the structure of the text through integrating the whole and the parts, and the others saw each components separately as 'facts' and thus distorted the structure: a *holistic* and an *atomistic* approach. Other studies have also showed similar results in students' approaches to learning and their relationship to the quality of their learning outcomes (i.e. Prosser & Trigwell, 1999; Entwistle, 1997;

Entwistle et al., 1992; Marton et al., 1997; Marton & Booth, 1997). Entwistle (1997) has added a strategic approach in which students organise their learning in order to achieve the highest possible learning outcomes (grades). The students are goal-oriented, extrinsically motivated and alert to assessments requirements and criteria. Students' approaches to learning are summarised in Table 2-1.

Deep Approach *Intention* – to understand ideas for yourself. Relating ideas to previous knowledge and experience. Looking for patterns and underlying principles. Checking evidence and relating it to conclusions Examining logic and argument cautiously and critically Becoming actively interested in the course content	***Transforming* by**
Surface approach *Intention* – to cope with course requirements Studying without reflecting on either purpose or strategy. Treating the course as unrelated bits of knowledge. Memorizing facts and procedures routinely. Finding difficulty in making sense of new ideas presented. Feeling undue pressure and worry about work.	***Reproducing* by**
Strategic approach *Intention* – to achieve the highest possible grades Putting consistent effort into studying. Finding the right conditions and materials for studying. Managing time and effort effectively. Being alert to assessment requirements and criteria. Gearing work to the perceived preference of lecturers	***Organizing* by**

Table 2-1 Approaches to learning (Entwistle, 1997: p19)

A. Variations and consistency in approach to learning

These studies into student learning have found both a consistency and variations in students' approaches to learning. In general students' approaches to learning are grounded on their orientations of learning. However, a student's approach to learning can also vary (Prosser & Trigwell, 1999; Ramsden, 1992; Laurillard, 1993). Students have adopted a different approach – either 'deep' or 'surface' in different subject matters or learning tasks (Laurillard, 1984). Laurillard (1984) found from one of the seminal studies that students change their approaches depending on the particular task in which they are engaged. In her interview study of 31 undergraduate science students, Laurillard found that 19 of them used different approaches on different occasions on different tasks, while 12 used the same approach. She concludes that students approached learning in the context based on their perceptions of the nature of the problem set and the teacher's requirement. The students approached to solve 'the problem-in-the-context' they *perceived*, which was different from the teacher's intention. This indicates that not only the tasks or subject matters but the learning context in which the students are engaged in learning also affect their approaches to learning.

Other studies into student learning also have found that students adopt an approach to learning as they see the context in which they learn affords (i.e. Ramsden, 1992; Prosser & Trigwell, 1999). Marton (1988) stresses that: 'Approaches to learning are not something a student *has*: they represent what a learning task or set of tasks *is* for the learner' (p.75, original italic)".

B. Approach to learning vs. learning outcomes

The studies in student learning (i.e. Marton & Saljo, 1984; Ramsden, 1992; Marton & Booth, 1997; Prosser & Trigwell, 1999) have found that surface approaches are related to poorer learning outcomes and students' dissatisfaction with their learning. Deep approaches to learning lead to high quality outcomes and better grades. Also, students find their learning more enjoyable (Ramsden, 1992), which increases their interest and motivation to study in future. Marton and Saljo (1984) emphasise the importance of students taking a 'deep' approach by saying: 'We are not arguing that the deep/holistic approach is always "best": only that it is the best, indeed the only, way to understand learning materials' (p.46). Prosser and Trigwell (1999) also assert that learning strategies can and should vary depending on the subject matter and learning context, but students should consistently adopt a 'deep' learning approach.

Ramsden (1992) asserts that in some areas, such as experiential learning or professional studies with a large amount of problem-solving activities, the approaches that students used are also the outcomes of learning. For example, in the case of experiential learning in a natural environment, the approach to solve a task is the result and the goal. Laurillard (2002) and Ramsden (1992) emphasise the importance of helping students change their approaches to a more desired one. Ramsden (1992) asserts that it can be achieved through changing students' experiences, perceptions or conceptions of learning. This further emphasises the importance of creating a learning context in which students perceive it affords a 'deep' approach.

From their study into Chinese students' learning, Marton et al. (1993) have found a distinction between two qualitatively different ways of seeing memorisation: one with intention to understand and the other, mechanical memorisation. Depending on students' intentions to memorisation, it could either lead to a 'surface' or a 'deep' approach. If students perceive 'memorising' as a means of reproducing knowledge, it will likely lead them to adopt a 'surface' approach, but if they use it in order to understand, then it will lead them to adopt a 'deep' approach. Ramsden (1992) stresses that the lecturer needs to distinguish the differences between knowing facts or understanding concepts and the different approaches.

> "An approach is not about learning facts versus learning concepts: it is about learning *just* the unrelated facts (or procedures) versus learning the facts *in relation to* the concepts. Surface is, at best, about quantity without quality; deep is about quality and quantity."
>
> (p. 45)

Biggs (1989) has put this:

> "Knowing facts and how to carry out operations may well be part of the means for understanding and interpreting the world, but the

> quantitative conception stops at the facts and skills. A quantitative change in knowledge does not in itself change understanding. Rote learning scientific formulae may be one of the things scientists do, but it is not the way scientists think.
>
> (p.10)

2.1.2. Factors influencing choice of approaches to learning

Studies into student learning (i.e. Prosser & Trigwell, 1999; Marton & Booth, 1997; Ramsden, 1992; Beard & Hartley, 1984) have identified several factors that are related to students' approaches to learning. Most significant are students' prior experiences with learning tasks or subject matters, their conceptions of learning, the learning context in which they study, their characteristics and personal situations.

A. Previous experience of learning

Students' prior experiences with tasks and subject matters

When students enter higher education, they come with experiences of learning. They have certain prior experience with learning, i.e. subject matters and tasks. Prosser and Trigwell (1999), in their constitutionalist model (Figure 2-1), illustrate the role students' previous experiences plays in their learning. Prosser and Trigwell describe that certain aspects of students' previous experiences are evoked by the learning context in which they learn and the factors evoked become the foreground of their awareness. What are in students' foreground awareness influence student learning including their choice of an approach to learning. For example, when a student faces a learning task, this evokes a similar experience in the past. If he or she took the 'surface' approach for the similar task in the past, then he or she is likely to take a 'surface' approach to the task. Prosser and Trigwell (1999) assert that the same happens with students' experiences with subject matters.

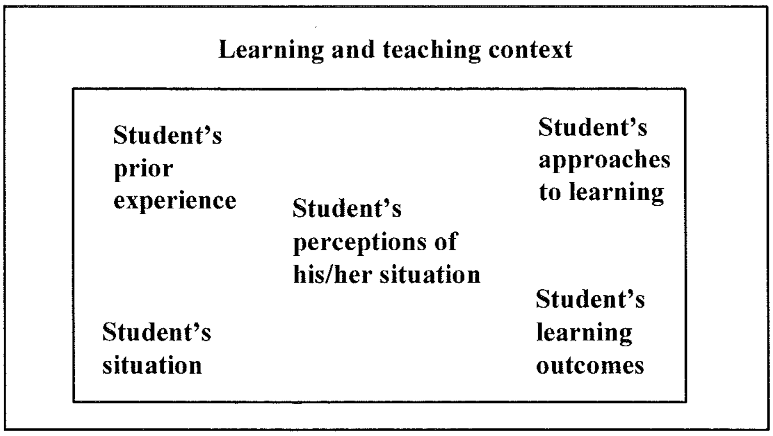


Figure 2-1 A constitutionalist model of student learning (Prosser & Trigwell, 1999)

Background knowledge

Another factor, which affects students' approaches to learning, is their background knowledge. It is most often related to the choice of students' approaches to learning in the science and technology departments. The reason is that when knowledge is hierarchically structured, an understanding of new concepts is often only possible if the previous stages have been fully grasped (Ramsden, 1992). In arts and social science, tasks or level of interest more commonly affects students' learning approaches (Entwistle & Ramsden, 1983).

B. Conceptions of learning

In addition to students' previous experience of learning, the second, most significant, factor related to students' approaches to learning is their conceptions of learning (i.e. Prosser & Trigwell, 1999, Marton & Booth, 1997; Ramsden, 1992). Saljo (1979) conducted an interview study and found five different understandings of learning among students. He classified the students' conceptions of learning into the five different categories.

Entwistle, Thomson and Tait (1992) have also derived similar categories from the research carried out at the University of Edinburgh investigating factors which influence learning in higher education. From this research they added another category to Saljo's:

the sixth category – developing as a person. The six conceptions of learning are summarised in Table 2-2.

	Learning as ...	
A	... increasing one's knowledge	***Learning as primarily reproducing***
B	... memorising and reproducing	
C	... applying	
D	... understanding	***Learning as primarily seeking meaning***
E	... seeing something in a different way	
F	... changing as a person	

Table 2-2 Conceptions of learning (Marton et al., 1993)

There are qualitative differences between the first three and last three. Learning in the first three conceptions is something external to the learner, and the last three emphasise internal or personal aspect of learning. Saljo (1979) stresses that the learning concepts are hierarchically structured; therefore, students who conceive of learning as understanding reality are also able to see it as increasing their knowledge. Ramsden (1992) explains this:

> 'Learning that involves a change in understanding implies and includes a facility with a subject's techniques and an ability to remember its details. These skills become embedded in our knowledge during the slow process of changing our understanding of a topic.'
>
> (p4)

Ramsden (1992) found that during the course of their studies many students' understanding of what learning consists of changes into a direction desirable. In order to improve student learning, he emphasises that teaching has to encourage rapid development of more sophisticated conceptions of learning. This can only be achieved if both the teacher and students become aware of the conceptions of learning students have and the variations between the conceptions.

C. Learning context vs. approaches to learning

The third factor, associated to students' approaches to learning, is the learning context in which they are engaged in teaching and learning. In their constitutionalist model (Figure 2-1), Prosser and Trigwell (1999) illustrate learning and teaching processes. When students enter a learning context, their personal situations and prior experiences evoke certain awareness. This leads students to perceive the same context differently as they all have different prior experiences and personal situations. Students' perceived learning situations influence the students to adopt an approach to learning that they see suitable for the task or the environment. The way students perceive their learning situations is evoked by their previous experiences, which include their prior learning approach. And the context in which the students learn evokes their prior learning experiences. Prosser and Trigwell (1999) describe the relationship as 'relational', and teaching and learning process as 'iterative'. With the same reason, lecturers also perceive the learning and teaching context differently. As a result, what and how the lecturers want their students to learn and what and how their students actually accomplish often differ (Laurillard, 2002; Ramsden, 1992; Beard & Hartley, 1984).

Emphasising the impact of the learning context in student learning, Laurillard (2002) asserts that lecturers require to create an environment in which students approach to learning as the lecturers intend. Ramsden (1992) also emphasises this:

> 'Students' thoughts and actions are profoundly affected by the educational context or the environment in which they learn. They react to the demands of teaching and assessment in ways that are difficult to predict. A lot of their learning is not directly about the subject but learning about how to please lecturers and gain high marks ... To achieve change in the quality of teaching and learning, we ought rather to look carefully at the environment in which a lecturer works and the system of ideas which that environment represents...'
>
> (p.7)

What in the learning and teaching contexts affect students' perceptions of the contexts and their approaches to learning? Ramsden (1992) identifies workload, assessment methods and the quality of teaching in the context as factors that affect students' approaches to learning. Heavy workload and assessments methods perceived to measure knowledge acquisition rather than understanding influence student learning negatively. Laurillard (1984) has found that approaches to problem-solving in science are related to the students' perceptions of marking criteria. Excessive competition among students influences negatively as well. Ramsden (1992) asserts that good teaching and collaborative learning environment encourage students to adopt a 'deep' approach and improve student intrinsic motivation to learn the subject matter.

Good teaching

What is 'good teaching? Ramsden (1992) describes that: 'Good teaching encourages high quality student learning' (p. 86). This implies that good teaching encourages students to adopt deep approaches to learning, promotes interest in the subject matter, and changes in students' conceptions of learning. Ramsden (1992) recommends six principles of 'effective' teaching, and they are as follows:

- Principle 1: Interest and explanation
- Principle 2: Concern and respect for students and student learning
- Principle 3: Appropriate assessment and feedback
- Principle 4: Clear goals and intellectual challenge
- Principle 5: Independence, control, and active engagement
- Principle 6: Learning from students

Laurillard (2002), Light and Cox (2001), Prosser and Trigwell (1999), and Ramsden (1992) emphasise that good teaching should and can be derived from understanding student learning.

Discussion and collaboration in the learning context

The pedagogical move from instructional design to constructivism (Section 2.2) and findings from studies in student learning have increased the emphasis on discussion and collaboration for student learning. The constructivist approach views discussion and collaboration as an essential aspect of learning because students become aware of different perspectives on a task (Cunningham, 1992). From the studies in student learning, Marton and Booth (1997), and Ramsden (1992) also emphasise the importance of discussion for learning. Ramsden (1992) asserts that discussion makes students' conceptions and misconceptions of an idea explicit. This helps students not only correct their conceptions but it also encourages them to develop their conceptions of learning to more desirable ones. From their studies into vicarious learning, Fowler and Mayes (2000) found that either direct or indirect experience of discussion influences learning.

In the UK, the idea of 'learning through discussion' dominates many of the National Curriculum documents (Laurillard, 2002). In practice small group discussion during a lecture or a tutorial has been encouraged as an effective learning activity, though staff shortage often makes such an activity difficult to support (Laurillard et al., 2000). The findings from the studies mentioned above and the educational practice with 'discussion' in the UK universities emphasises the importance of facilitating dialogue and discussion in the learning context.

D. Characteristics of students: motivations

Students' motivations affect their approaches to learning and their learning outcomes. Students who are intrinsically motivated to learn and have an interest in the subject matter are more inclined to adopt a 'deep' learning approach (Ramsden, 1992; Entwistle et al., 1992). Students who adopt either a 'surface' or 'strategic' approach are found to be extrinsically motivated to learn (Entwistle et al., 1992).

Instead of 'motivation', Ellington et al. (1984) use the term 'wanting to learn' in describing it as one of four ingredients for successful learning experiences: wanting, doing, feedback and digesting. In addition, Light and Cox (2001), from their study in teaching and learning, illustrate the development of student learning with 6 stages and identify five learning gaps that lie between them. The six stages include recall, understanding, ability, wanting to, doing and changing. They stress the importance of a learning environment supporting the development of 'wanting to', and emphasise that it involves much more than providing knowledge and skills.

> "A genuine 'wanting to' requires significant degree of change in many of the ways students perceive and understand knowledge and the world in which their intellectual, personal and social commitments must be made."
> (p.58)

Other factors found from motivational studies are 'sense of involvement', 'challenge', 'achievement', 'feelings of personal fulfilment' and 'pleasure', which lead to a 'deep' approach (Ramsden, 1992; Beard & Hartley, 1984). Students' feelings of resentment and dissatisfaction to the course, depression, and anxiety are associated to a 'surface' approach (Beard & Hartley, 1984; Ramsden, 1992).

E. Personal situations

The factors which affect students' approaches to learning identified so far are: their previous experience of learning, their conceptions of learning, the learning context, and their motivations to learn. In addition, students' personal situation affects their approaches to learning. Prosser and Trigwell (1999) explain that students' personal situations evoke certain factors in their awareness, which makes each student perceive the affordances of the learning context differently.

Secondly, students are sometimes led by their personal situations to choose a 'surface' approach even if they perceive the learning context affords a 'deep' learning. Both number and diversity of students are increasing in the UK higher education, and students' personal situations vary. For example, there are mature and part-time students who have other commitments, and many have a part-time job. Also, the number of overseas students is increasing. Their different cultural backgrounds and learning experiences require much support – both academic and cultural.

2.1.3. Teaching and learning processes

Learning processes

Most academic knowledge is acquired indirectly through the descriptions of the world, which Laurillard (2002) calls 'mediated'. Laurillard (2002) asserts that in order for students to acquire knowledge indirectly experienced, learning activities need to support them to make their conceptions explicit. Also, the learning activities should help the students correct and elaborate their conceptions. Prosser and Trigwell (1999) describe the learning process with 'acquiring', 'knowing' and 'applying' phases. They argue in their constitutionalist model, that there is no logical ordering of parts in the process as each part is constituted in its relation to the other parts as a whole. From literature in student learning, Laurillard (2002) also derives three aspects of the learning process, which are:

- the integrative nature of the learning process: 'relational' and 'iterative' by nature,
- the inseparability of knowledge and action, and
- the inseparability of process and outcome.

From the finings from the literature, Laurillard (2002) also derives five aspects of learning that have to be supported as an integrative whole, and they are:

- apprehending structure;
- interpreting forms of representation;
- acting on the world (of description);
- using feedback;
- reflecting on goals-action-feedback.

Learning and content

Marton and Booth (1997) have conducted several studies attempting to encourage students to take reflective and interpretive approach to their learning (p. 168 - 171). The techniques they used are focusing the students' awareness on the act of learning itself by including in a text instruction on how to read it, to reflect on it and to summarise it. In all cases, students responded by focusing on the guidance rather than the context of the text which undermined any meaningful outcome they might otherwise have derived.

Laurillard (2002) has carried out a similar study: a learning skills programme for history students and making use of history materials as the focus of reflection and obtained a more successful result. This integration of content with process has resulted in a more advanced conception of learning. Laurillard (2002) asserts that the separation of content and process technifies the learning process, making the instructions themselves the object of learning. The same can be often found with IMM learning applications. Learners focus on operating the IMM applications rather than focusing on learning the content.

Teaching to facilitate learning

Learning in higher education concerns what students learn but more how they learn, because transferable skills such as problem solving skills, critical thinking and etc. are more important than the domain knowledge gained (Laurillard, 2002; Marton & Booth, 1997; Ramsden, 1992). As discussed in Section 2.1.1, students' approaches to learning are intrinsically related to the environment in which they study. In order to encourage students to adopt a 'deep' approach to learning, first of all, lecturers need to create a context which not only afford a 'deep' learning but in which students perceive it affords a 'deep' learning. Secondly, in order to encourage students to adopt a 'deep' approach to learning, the lecturers need to facilitate learning activities that support the learning process. Thirdly, they should help students become aware of different approaches to learning and what can lead to better learning (Ramsden, 1992).

Teaching and learning processes

Teaching and learning are an inseparable process, and in order to improve teaching, it has to start from understanding student learning (Ramsden, 1992; Prosser & Trigwell, 1999; Marton & Booth, 1997; Light & Cox, 2001; Laurillard, 2002). Since Pask (1976) formalised the idea of learning as a conversation in Conversation Theory, many describe learning and teaching process as 'dialogue' or 'conversation': Prosser and Trigwell (1999) as an 'iterative' process, Kolb (1984) as 'an iterative cycle', and others as 'dialogue' (Ramsden, 1992; Laurillard, 1997; Light & Cox, 2001).

Facilitating student learning in this context means supporting the 'iterative' process between teaching and learning or 'dialogue' between the lecturer, the student and the content. Laurillard (2002) argues it as the only prescriptive implication for learning, and this shifts the focus of teaching from what the teacher should do, to how they must set up the interaction:

> '...a continuing iterative dialogue between teacher and student, which reveals the participants' conceptions, and the variations between them, and these in turn will determine the focus for the further dialogue.'
>
> (p.71)

In addition to creating an appropriate learning context that affords a 'deep' approach to learning and to facilitating learning activities, lecturers also need to provide more personal support. Personal support can create a more positive atmosphere in the learning environment, and this can influence how students view the subject matter they are studying (Light & Cox, 2001). The students' views on the subject matter are significantly related to their future career.

Institutional intervention

Laurillard (2002) emphasises the importance of institutional intervention asserting that 'Think differently' in teaching does not make 'act differently." Not only learning but teaching also is very much bound to the environment (Light & Cox, 2001; Ramsden, 1992). Lecturers approach teaching the same way as students: they adopt an approach to teaching as they perceive the teaching context affords (Prosser & Trigwell, 1999). The reason is that lecturers are subject to the institutional demands, i.e. research, administrative work and etc. Thus, even if a lecturer desires to approach teaching differently, it is difficult to achieve without institutional supports, i.e. providing staff development, supporting innovation in teaching and etc.

2.1.4. Implications for IMM courseware design

Laurillard (2002) and Ramsden (1992) emphasise that in order to improve teaching, it should start from understanding student learning from students' perspectives. This suggests that in order to facilitate students' learning with IMM learning materials, we should start it from understanding teaching and learning processes from both lecturers' and students' perspectives.

In terms of student learning in higher education, studies have found that their learning experience differ depending on their approaches to learning. As discussed in Section

2.1.1, students approach to learning in two main different ways: 'deep' or 'surface'. A primary difference between the two approaches is students' intentions of learning. With deep approaches, students focus on seeking 'meaning' in their learning, and with surface approaches, students focus on reproducing what they learn. The differences in students' approaches to learning produce the differences in the quality of learning outcomes.

As discussed in Section 2.1.1 and Section 2.1.2, students' approaches to learning are not something students have but they adopt as they perceive the task or the subject matter that they study affords in the learning context. Students' previous experience, conceptions of learning and motivations influence their choice of approaches to learning. In addition, the learning context in which students are engaged in learning affects students' approaches to learning. Depending on how students perceive the learning context provides, they can adopt either a 'surface' or 'deep' approach.

As for teaching and learning processes, the student, the lecturer and the content are interrelated in the teaching and learning context. How lecturers approach teaching affects how students perceive and experience learning. As discussed in Section 2.1.3, to facilitate student learning, lecturers need to create a learning environment in which students perceive it affords 'deep' learning and to provide learning tasks that promote the learning process.

If we design an educational IMM courseware to support independent learning, the IMM courseware will need to take the role of the lecturer in the teaching and learning processes. If we aim to facilitate student learning with IMM courseware through supporting both teaching and learning, it needs to be designed in a way that can support teaching and learning processes in the context. This thesis proposes to facilitate student learning by integrating IMM courseware for both teaching and learning. This means that

IMM courseware will become part of the learning context in which students experience and perceive their learning. As Mayes and Fowler (1999) assert, the usability and effectiveness of educational IMM courseware depends on how effectively it supports learning in the educational context. IMM courseware needs to be designed suitable for the learning context, and it should be integrated into the learning context in a way to encourages students to adopt a 'deep' approach to learning. In order to achieve these, IMM courseware should be designed and integrated to support the learning and teaching processes in the context. Further literature has been reviewed in theories of learning in order to understand the psychological perspectives of learning and its implications for IMM courseware design. This is presented in next section.

2.2. Theories of learning

The previous section presented a review of how students experience learning in higher education, the factors affecting students' approaches to learning, and teaching and learning processes. These provide useful insights in integrating and designing IMM courseware for teaching and learning in a learning context. However, in order to facilitate learning effectively with IMM, a courseware designer should understand psychological aspects of learning too. There are two main theories of learning from cognitive psychology: instructional design and constructivism. Theoretical assumptions of the two theories of learning and their implications for designing IMM courseware for learning will be discussed in this section.

2.2.1. Instructional design

Instructional design theory is rooted in an objectivist tradition: it is emerged from behaviourism and derives some empirical ground on some aspects of cognitive psychology, i.e. information processing theory. Objectivism assumes that the world is completely and correctly structured in terms of entities, properties and relations (Lakoff, 1987), and knowledge exists independently of instructions (Merrill, 1992; Duffy & Jonassen, 1992). Thus, learning is viewed as the process of the transmission and acquisition of knowledge structure – in their word, a process of constructing of a mental model of a particular type of knowledge. The goal of instruction is to help the learner acquire the entities, relations and the attributes of each to build "the" correct propositional structure (Duffy & Jonassen, 1992). In order for adequate instruction to occur knowledge must be pre-specified in some forms of knowledge base. Diverse domain knowledge can be represented using the same knowledge structure.

The next assumption is that the structure of individuals' mental model is the same even though the content of each individual's mental model may be different: the functioning of mind – encoding, memory and retrieval. The third assumption is that the learner constructs a mental model as a result of experience. Learners can interact with knowledge in a variety of ways, but that certain types of interactions are necessary if a leaner is to acquire a particular type of knowledge or skill. Fourthly, pre-specified instructions can enable these interactions and thus enable a learner to construct appropriate mental models of a particular type of knowledge (Merrill, 1992). Since instructional design assumes knowledge and instructions can be pre-specified, they also assume that the mental model of the learner can be objectively tested. Often their instruction starts from testing the learner's knowledge and specifying what to be learned and what instructions to be used. The learner's learning outcomes are tested against pre-defined criteria in a systematic way.

In terms of applying instructional design in educational courseware design, it is a prescriptive methodology which specifies instructional goals (learning outcomes) and external (situational) conditions for learning in details (Duffy & Jonassen, 1992; Laurillard, 2002). There are three main phases in instructional design - needs analysis, selection of instructional methods and materials, and evaluation. Needs analysis involves analysing the nature of the task precisely in relation to the goals and identifying every sub-task the student must do and every piece of knowledge the learner must acquire. This analysis normally produces a hierarchical classification where goals are broken down into sub-goals and the content required to achieve the lowest sub-goals is specified. Then the objectives of the teaching are specified in terms of measurable outcomes, and the test methods are specified (Phillips, 1997). In this needs analysis phase, a test is quite often carried out to measure the learner's knowledge and determine instructions required.

The next phase is selecting the instructional methods and resources. The prescriptions of instructional theory are used to guide this process. Price (1991) recommends a sequence of nine teaching events derived from the theories of Gagne and his colleagues (Gagne & Briggs, 1979) to ensure each learning process happens and each objective is achieved. The last phase is evaluation. Evaluation is carried out by assessing if every instructional goal is achieved. Since the development of the instructional framework is iterative, prototypes are developed and assessed through formative assessments until the required level of performance is achieved. Before releasing an educational material, one final summative evaluation is carried out (Boyle, 1997).

This approach has been criticised in the light of major developments in psychology and computer technology (Phillips, 1997). In modern psychology, learning is viewed as a dynamic process: the learner actively constructs their knowledge through interacting with the world. Knowledge is viewed not as something that exists independently of the learner in the world. Boyle (1997) criticises that instructional design, reasoning that teaching is not to impose the knowledge structure but to facilitate the constructive learning process. Bednar et al. (1992) reject the assumption that types of learning can be identified independent of the content and the context of learning. Instead of dividing up the knowledge domain based on a logical analysis of dependencies, a consideration has to be given to what real people in a particular knowledge domain and real life context typically do (Brown et al., 1989; Resnick, 1987).

Laurillard (2002) criticises that instructional design is insufficient to provide a holistic understanding of student learning because of its tenuous link to empirical base. In her critique of instructional design, she argues that although information processing theory from cognitive psychology has empirical bases, they are derived from isolated experiments to suit their purposes. Learning cannot and should not be determined in this way.

Another area criticised is that instructional design specifies a category of instructional objectives and instructional designers plan for each instruction. Decomposing knowledge to specify instructional goals into a hierarchical structure and to pre-specify instructions to achieve each goal, it does not approach learning as a whole or holistically. This has been admitted as a limitation by instructional design, which they have tried to remedy by adding 'integrative goals (enterprises)' to their definitions of the types of human capabilities: intellectual skills, verbal information, cognitive strategies and etc. (Gagne & Merrill, 1990, p. 2). Laurillard (2002) criticises this saying:

> '... it is not possible to effect a synthesis of those analytical components simply by drawing a circle round them... and then naming it. 'Integrative goals', and 'holistic student interactions' have to be derived from studies that look at interactions holistically. Their enterprise is word games; it is not science.'
>
> (p. 66)

In the area of assessment, Cunningham (1992) criticises it by saying: 'objective measurement is a fiction or at best a degenerative case where knowledge is so decontextualised that only one context (school context) is relevant.' However, there is a positive side of instructional design: the strong emphasis on needs analysis which has been neglected in many areas of educational planning (Laurillard, 1993). Also, it offers clear instructional guidelines useful in educational courseware design.

2.2.2. Constructivism

Constructivism views that the learner, through interacting with the world, *constructs* knowledge of the world. Constructivism, depending on its roots, is divided into two: 'cognitive constructivists' and 'socio-cultural constructivists'. The former is rooted in Piaget's work which he called 'generic epistemology', from his study investigating children's development of increasingly abstract constructions of their world (1970). The latter is rooted in Vygotsky's description of the development of knowledge through social interaction and the later idea of 'situated cognition' (see Chaiklin & Lave, 1993; Lave & Wenger, 1991; Lave, 1988; Suchman, 1987).

Constructivists view the learner as active constructors of their knowledge of the world (Duffy & Jonassen, 1992), and meaning is imposed on the world by the learner. Learning is viewed as an active process of constructing knowledge, and instruction as a process of supporting that construction, rather than transmitting the knowledge (Duffy & Cunningham, 1996). Constructivism is concerned with what the students can bring to their own learning, rather than how they are taught (Phillips, 1997). Constructivists assume that when the learner interacts with the world, internally they reconstruct existing knowledge structures linking a new knowledge structure constructed. In other words, the learner brings their own experience to learning - what they have learned in the past and the knowledge they have, and it influences the way they construct knowledge. Each individual has their own views and understandings of the world.

Since constructivists view the learner constructs their knowledge through interacting with the world, they argue that learning experience must be 'situated' in real-world contexts (Brown et al., 1989; Resnick, 1987; Rogoff & Lave, 1984) and 'meaning is rooted, and *indexed* in, experience (Brown at el. 1989). Knowledge emerges in contexts to which it is relevant (Cunningham, 1992), and therefore, learning must be situated in the domain of its objectives. Resnick (1987) argues the lack of knowledge transfer between in and out of school environments is resulted from the decontextualisation of learning. Learning always takes place in a context and the context forms an inexorable link with the knowledge embedded within it. With the same reason, constructivists emphasise problem-solving with authentic tasks and experiential learning.

Spiro (1988) argues that learning environments must not be simplified. Instead of dividing up the knowledge domain based on a logical analysis of dependencies, the constructivist view turns toward a consideration of what real people in a particular knowledge domain and real life context typically do (Brown et al., 1989; Resnick, 1987). The overarching goal is to move the learner into thinking in the knowledge domain as an expert user of that domain might think. They propose that cognitive apprenticeship (see Collins et al., 1988) and scaffolding assisted from a teacher can achieve it when the learner could lack knowledge or experience to do it by themselves. In the constructivists' view that the role of the teacher is: to provide authentic tasks or real world problems, and to create projects or environments that capture a larger context in which that problem is relevant, and to assist or guide students to construct their own knowledge through solving problems.

Constructivists emphasise collaboration between students. In constructivists view, meaning is negotiated (Cunningham, 1992) as meaning is imposed by individual learner's experience. Each individual has different learning experience and their understanding varies. Collaborative work is emphasised in order for the learner to share their different views on tasks and problem-solving approaches. This would enable the learner to become aware of multiple perspectives and to have more critical in their learning process. As discussed in Section 2.1.2, the importance of discussion and collaboration is emphasised in the UK higher education.

Although constructivists agree that knowledge is constructed by the learner, there is a dispute regarding how it should be supported: BIG (beyond the information given) – more moderate view and WIG (without the information given) – extreme view. The advocates of BIG argue that one can quite straightforwardly teach concepts, providing the overall instructional experience that includes ample occasions for students to test and extend their evolving conceptions (Bruner, 1973). The advocates of WIG argue that concepts are not truly and meaningfully learned in ways that empower learners unless those concepts are in good part rediscovered by the learners. They emphasise that the teacher's guidance needs to be a minimal since every individual experiences learning differently. Bednar et al. (1992) argue that the content should not be specified; 'we simply cannot define the boundaries of what may be relevant.'

Another difference of constructivism from instructional design lies in evaluation. The difference is in the intention of evaluation. While instructional design assesses the learning outcomes pre-specified, constructivism examines the thinking process (Bednar et al. 1992; Cunnigham, 1992). Constructivists view that learning outcome is within the learning process. Since each learner comes to learning differently and there is not one correct way to solve a problem, objective assessment is viewed impossible. Cunnigham (1992) asserts that learning outcomes can be assessed by seeing if the students can successfully construct plausible solutions to the tasks they are presented and by checking to see if the student is developing self-awareness of the constructive process.

Some of constructivist views, particularly extreme constructivists' views, are criticised. For example, Marton and Booth (1997) criticise individual constructivist view on the learner constructing their own world as 'isolated solipsistic constructions of in the individual minds.' In terms of teaching strategy, constructivist Perkins (1992) suggests that: 'education, given over entirely to WIG constructivism would prove grossly inefficient and ineffective, failing to pass on in straightforward ways the achievements of the past.'

Laurillard (2002) also asserts that although constructivism offers a principled approach to facilitate and optimises the learning processes, it does not focus on the students' roles of what they must do to learn. She also argues that constructivism has no focus on empirical findings on student learning and no means to build further understanding of the learner. As for the reason, she cites that cognitive psychology produces generalised but not content-specific principles and theories of learning. It does not clarify the logic of the relationship between the cognitive activity and the content to be learned.

2.2.3. Different views on instruction design

There are differences in terms of how instructional design and constructivism view learning, and so are in the integration of learning theory and educational material design. Reigeluth (1983) suggests that instruction designers require prescriptive instructional theory - a set of specific methods for manipulating the instructional environment along with the conditions under which each specific set of manipulations should be used to produce desired learning outcomes. More importantly, he argues that a prescriptive instructional theory may be independent of learning theory – the descriptive theories do not need to consider the assumptions we are making about the learning process and what it means to learn and understand. Many from both instructional design and constructivism reject his descriptive learning theory and prescriptive learning theory on the basis that the learner *constructs* knowledge – even though 'how' is assumed differently between two theories.

Another difference comes from views on distinguishing levels of learning and instructional design. In describing a continuum of knowledge acquisition from ignorance to expertise: introductory, advanced and expert phases, Jonassen et al. (1993) suggest that instructional design is suitable for introductory learning and constructivist approach is more suitable when the learner acquires some knowledge in a domain. It is described as:

> '... introductory knowledge acquisition is better supported by more objectivistic approaches, such as those implicit in classical instructional design models, with a transition to constructivistic approaches that represent complexity and ill-structuredness as the learners acquire more knowledge. The latter part of the initial knowledge acquisition phases may be supported by more constructivistic approaches ...'
>
> (1993)

This seems to advocate somewhat BIG constructivism view on learning. However, this recommendation implies that if instructional design and constructivism offer different teaching and learning strategies, which they are, the learner may need to change their learning approaches. Bednar et al. (1992) question the wisdom of differentiating levels of learning (see Jonassen et al. 1993; Spiro et al, 1992; Spiro, 1988) by asking:

> '... Is it reasonable to differentiate levels of learning – for example, introductory learning from advanced knowledge acquisition (Spiro, 1988) or memory from problem solving – and to apply different instructional techniques based on different theories, or does that imply that you must believe the nature of knowing, what it means to know, changes between introductory and advanced levels?
>
> (p. 31)

They argue that:

> '... in those situations where the assumptions lack consistency, we must adopt a consistent set of assumptions and reject the findings of research and the development of theory based on different assumptions ... One of the practices which requires scrutiny is the practice of drawing from fields with different theoretical bases without examining the conflict between the basic assumptions of those theories. Optimally, ... tie our prescriptions for learning to a specific theoretical position – the prescriptions would be the realisation of a particular understanding of how people learn ... Minimally ... be aware of the epistemological underpinnings of our instructional design and the consequences of that epistemology on our goals for instruction, our design of instruction, and on the very process of design.
>
> (Bednar et al, 1992: p.31)

Others echo that instruction design has to be firmly grounded on one theory of learning: 'Theories of learning and prescriptions for practice must go hand and hand (Carroll & Campell, 1988). Perkins (1992) in describing a constructivistic view of learning suggests that:

> '... Central to the vision of constructivism is the notion of the organism as "active" ... Even when the learning process appears to be relatively straightforward, say a matter of learning a new friend's name ..., constructivist processes operate: Candidate mental structures are formed, elaborated, and tested, until a satisfactory structure emerges. If learning has this constructive character inherently, ... need to be supportive of the construction that must occur.'
>
> (p.49)

Phillips (1997) asserts that: 'IMM learning materials should incorporate instructional design and constructivism, although the balance should be different for every application.' As discussed in this section, there are different theories of learning – instructional design and constructivism. Furthermore, there are different approaches to instructional design. Some recommend that designers incorporate both theories of learning in instructional design of learning materials. Others argue that instructions should be designed based on one theory of learning. Instructional designers must carefully assess the approach he or she would take in terms of the type of a material, the user and the context in which the material would be used.

2.2.4. Implications for IMM courseware design and integration

The design process of educational IMM courseware has greatly emphasised the importance of needs analysis, which includes identifying the needs of the user, the aim and objectives of the courseware, and the learning context in which the courseware is used (i.e. Perkins, 1992; Merrill, 1992). Despite of the emphasis on needs analysis, many educational materials have been found unsatisfactory. As Laurillard (2002) points out, it is not just by the poor quality teaching they provided, but the reason is neglect of embedding the materials in their educational niche. She asserts that: 'There is plenty of traditional teaching on offer in universities that is poor in quality, sustained nonetheless by its fit with the learning context.' She stresses this as one of the key reasons why many educational materials have made relatively little impact in higher education despite their potential.

This raises a question in terms of educational courseware design and integration: 'if an educational material is designed on sound needs analysis, then shouldn't it fit into its learning context and facilitate the teaching and learning processes effectively?' This suggests several possible causes. Firstly, there could be a bigger gap between the context analysed and the actual learning context than the designer or the user (the lecturer or institution) anticipated. For example, some contextual factors may have been unpredicted or overlooked in the analysis phase, i.e. the students' workloads, assessment methods, timetable or etc. Secondly, the actual use of an educational material within its learning context may not match the one intended. Thirdly, if the educational material is purchased, the pedagogical belief on learning may differ between the designer and the instructor, then the instructor will use it as he or she intends rather than the designer prescribed. Duffy et al. (1993) describe this:

> "... Instructional designers often report that they have difficulty getting the instructor to follow the instructional plan. ... one of the reasons for this is that the instructor very likely will have different goals for learning and a different concept of what it means to "understand" the subject matter. That is, the instructor will have a different theory of learning and will modify the instructional prescriptions to accommodate that theory. Hence the instructor will seek to supplement or replace content and strategies with approaches that he or she feels will lead to the "appropriate" understanding of the subject matter by the student."

There are many similarities in designing IMM courseware to facilitate learning and designing teaching to improve learning as they share the same aim of supporting learning. For example, without understanding student learning from students' perspective, it is difficult to design good teaching and so is educational courseware. However, in terms of designing IMM courseware it is essential to understand both teaching and learning processes from students' and lecturers' perspectives in their teaching and learning context, rather than the designer's. As lecturers try to find a way to bridge the gap between what and how they want their students to learn and what and how their students end up learning, designers should find a way to bridge the gap between how they want it to be used and how it is actually used.

Next section presents further review in frameworks which illustrate the learning process and interactions required between students and lecturers for learning. These frameworks are used in assessing the usability of the integration approach and IMM courseware design, which this thesis proposes (Chapter 4).

2.3. Frameworks for learning

Literature review into student learning and theories of learning has informed that learning and teaching are 'dialogic', 'reflective' and 'iterative' processes. Students construct knowledge through linking, elaborating and reconstructing through interacting with the lecturer and the content. Mayes' learning framework and Laurillard's conversational framework illustrate what constitutes the learning process and how it can be supported. Examining the frameworks will enlighten the design and integration of IMM courseware for teaching and learning.

Mayes (1995) derives a framework called 'Learning Framework' from cognitive psychology – constructivism, and this illustrates the learning process. He has later modified the learning framework putting emphasis on dialogue and reflection in knowledge construction. These two frameworks share similarities as they both view 'dialogue' as the 'vehicle' for conceptual movement (Fowler & Mayes, 1997). However, whereas the learning framework illustrates internal model of the learning process with 3 learning stages, the conversational framework is a descriptive model. The conversational framework describes the elements and interactions involved in the learning process: teacher, student and content; and the interactions between them to facilitate the learning process.

2.3.1. Mayes' learning framework

Mayes (1995) offered the first learning framework to illustrate the learning process which consists of three learning phases: conceptualisation, construction and dialogue (Figure 2-2). This framework has been used to test the usability of educational courseware.

His description of learning phases follows:

- **Conceptualisation:** '... refers to the student's initial contact with a learning material ... achieved by attending a lecture, reading textbooks ...using IMM learning materials.'
- **Construction**: '... build on the concepts learned in the conceptualisation phase and refine their understanding by working on further tests ...
- **Dialogue**: ' ... refine their understanding through dialogue and discussion ... having informal and sometimes impromptu conversations.

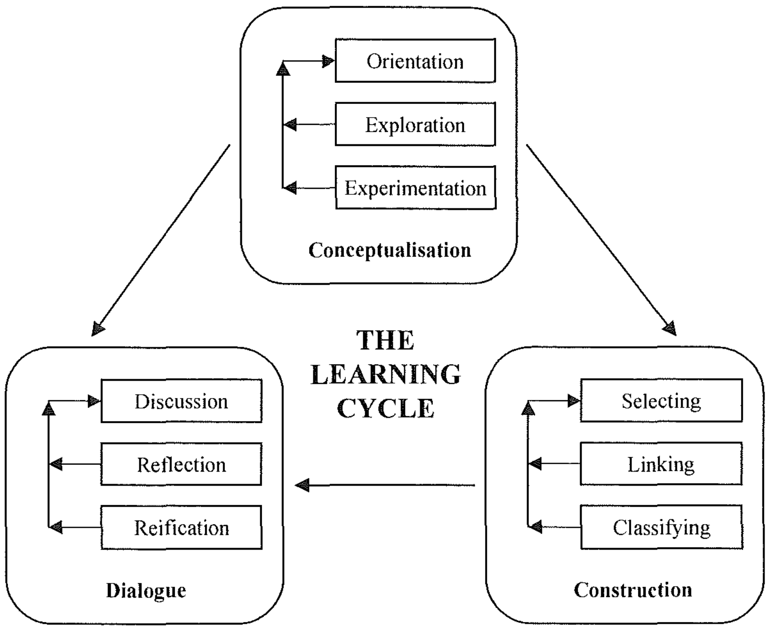


Figure 2-2 Learning framework (Mayes, 1995)

Fowler and Mayes (1997) have later modified the learning framework (Figure 2-3) by expanding the notion of dialogue into the three phases. This includes dialogues or learning conversations for clarification and confirmation at the conceptualisation phase, and dialogue for co-operation and collaboration at the construction phase. They also replaced the dialogue phase with 'identification' in which students reached a sufficient level of understanding to be able to relate to other conceptualisations - the existing knowledge and thus begin the process again. At this level, the existing knowledge is also reconstructed in light of the new knowledge gained (Duffy & Jonassen, 1992).

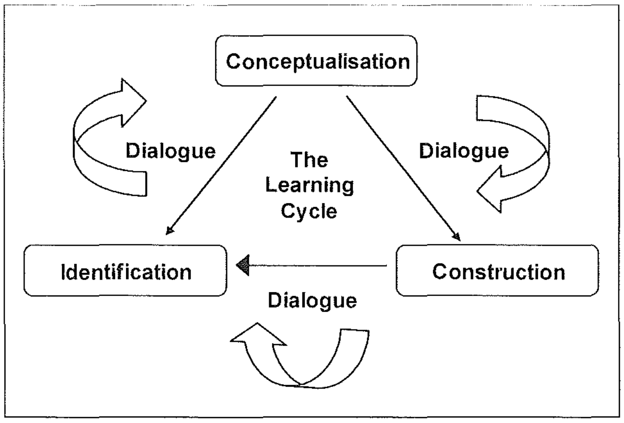


Figure 2-3 New learning framework (Fowler & Mayes, 1997)

The learning framework does neither explicitly specify the interactions required to construct knowledge between the learner and the learning environment nor define the roles of the teacher or the student to conduct it. It presupposes the learner's 'active' construction of knowledge through interacting with the learning environment, whether it is a lecture or IMM courseware.

However, it identifies cognitive activities that need to be facilitated by IMM courseware and defines the role of dialogue in learning. The interactions, dialogue, in Laurillard's Conversational Framework, is to illustrate the whole learning process (see Section 2.3.2). The 'dialogue' in the learning framework is something that moves the learning phases forward: 'the 'vehicle' for conceptual movement' (Mayes & Fowler, 1999). What promotes this dialogue? It is something that is conducted to satisfy internal needs and it is something that triggers learning activities when conducted directly or even indirectly without a clear intent. It is considered in this thesis that the 'internal needs' promotes 'internal' dialogue which sometimes is externalised. While learning, students think and reason (Soper, 1997). The students raise many questions internally such as 'why', 'how' and etc. All these internal activities result in the student reflecting on their existing knowledge or conducting external dialogue if their thoughts are not clarified internally.

Fowler and Mayes' learning framework depicts the learning process and a model of how IMM courseware to support it. They identify three different types of learning materials to support the learning process: primary, secondary and tertiary courseware. The primary courseware generally contains resources, and it can support the conceptualisation phase. As for the secondary courseware, they can be tools or educational courseware that contains tasks with which students can construct knowledge through testing or applying their understanding in problem-solving. The tertiary courseware is to promote dialogue. This learning framework offers useful guidance in identifying what learning activities IMM courseware should support in the learning context. The integration approach and IMM courseware design, will be proposed in Chapter 4, aims to support Fowler and Mayes' learning framework.

2.3.2. Conversational framework

The Conversational Framework (CF) defines the relationship between the teacher and the student, and it illustrates interactions required to support the learning process (Laurillard, 2002). The essence of the CF is grounded in the assumption that the learning process must be constituted as a dialogue between the teacher and students. Laurillard (1993) developed the CF from analysing 1) characteristics of teaching and learning process and 2) 'learning activities' to be supported from the findings of phenomenographic studies in student learning. As a result, the CF specifies the interactions required between the teacher and students for learning. The characteristics of teaching and learning process which teaching strategy has to facilitate are:

- **Discursive:**
  - the teacher's and student's conceptions should each be accessible to the other;
  - the teacher and student must agree learning goals for the topic;
  - the teacher must provide a discussion environment for the topic goal, within which students can generate and receive feedback on descriptions appropriate to the topic goal.

- **Adaptive:**
  - the teacher has the responsibility to use the relationship between their own and the student's conception to determine the task focus of the continuing dialogue;
  - the student has the responsibility to use the feedback from their work on the task and relate it to their conception.

- **Interactive**
  - the teacher must provide a task environment within which students can act on, generate and receive feedback on actions appropriate to the task goal;
  - the students must act to achieve the task goal;
  - the teacher must provide meaningful intrinsic feedback on their actions that relates to the nature of the task goal

- **Reflective**
  - the teacher must support the process in which students link the feedback on their actions to the topic goal for every level of description within the topic structure;
  - the student must reflect on the task goal, their action on it, and the feedback they received, and link this to their description of their conception of the topic goal.

(Laurillard, 2002: p,78)

This strategy offers useful insights in the design and integration of IMM courseware with its prescriptive form of interactions between teacher and student, rather than action on the student alone. This helps define what interactions IMM courseware to support and how to support the. For example, some interactions can be supported by the IMM courseware itself and others can be designed by the integration of the courseware in the learning context. Especially, the integration approach and IMM courseware proposed in Chapter 4 aim to support teaching and learning. This means the IMM courseware needs to be designed to support the required interactions in the CF not *by* itself alone, but rather through enhancing teaching and learning processes *with* it in the educational setting.

The second base of the CF is certain learning activities which Laurillard (2002) argues essential for learning. The learning activities, and the roles of the teacher and the student to achieve them are summarised in Table 2-3.

Aspects of the learning process	**Students' role**	**Teacher's role**
Apprehending structure	Look for structure. Discern topic goal. Relate goal to structure of discourse	Explain phenomena. Clarify structure. Negotiate topic goal. Ask about internal relations.
Interpreting forms of representation	Model events/systems in terms of representation. Interpret forms of representation as events/systems.	Set mapping tasks between forms of representation and events/systems. Relate form of representation to students' view
Acting on descriptions	Derive implications, solve problems, and test hypotheses, to produce descriptions.	Elicit descriptions. Compare descriptions. Highlight inconsistencies.
Using feedback	Link teacher's redescription to relation between action and goal, to produce new action on description	Provide redescription. Elicit new description. Support linking process.
Reflecting on goal-action-feedback cycle	Engage with goal. Relate to actions and feedback.	Prompt reflection. Support reflection on Goal-action-feedback cycle.

Table 2-3 Student and teacher roles in the learning process

From the characteristics of teaching and learning process and the learning activities required for learning, the CF illustrates 12 kinds of actions and interactions of the teacher and student, all of which, Laurillard (1993) argues, must occur for learning to occur satisfactorily. They are diagrammed in the Figure 2-4.

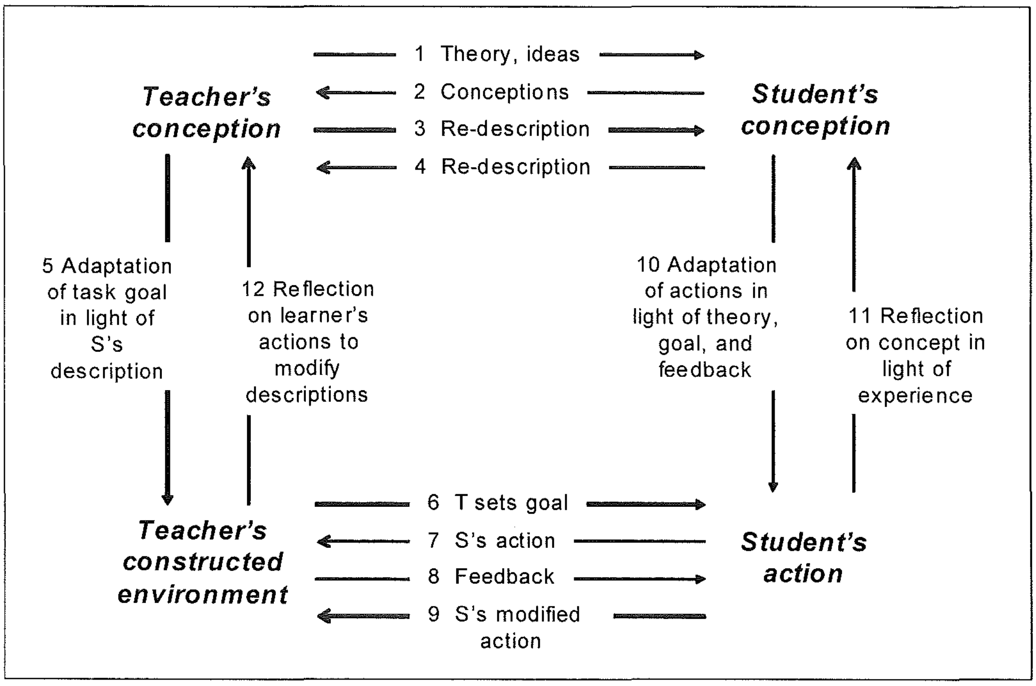


Figure 2-4 The conversational framework (Laurillard, 2002)

The CF does not describe the internal process of learning process, but it specifies the learning activities to be supported and the interactions required to facilitate the learning activities. The interactions and learning activities presented in the CF provide a useful guideline for the design and integration of IMM courseware. In addition, the CF is a useful framework in analysing and assessing educational materials including IMM courseware to determine whether the materials facilitate the interactions required.

A particular importance of the CF is its emphasis on reflection. The CF illustrates how feedback on actions promotes reflection. Laurillard stresses the importance of reflection in learning and a lack of supporting it.

> 'Reflection is rarely supported … Reflection is that part of the process where the learner has to consider the implications of their experience, the teacher's description and their own previous conceptions, and bring all these together into a coherent new description – the culmination of the learning process in new conceptual knowledge. It is important and difficult, and largely inaccessible to the teacher because it is internal to the learner. Nevertheless, the teacher has a

> responsibility to promote it, and encourage it somehow – we cannot assume that all learners will do it. Reflection takes time, and effort, and it needs to be contiguous with the appropriate experience.'
>
> (1995)

Learning is 'reflective' and 'interpretive' process (Prosser & Trigwell, 1999), and IMM courseware needs to be designed and integrated to promote reflection as much as possible. This is an area that requires further research in exploiting IMM to facilitate learning through promoting reflection. The integration approach and IMM courseware design, will be presented in Chapter 4, aim to support the interactions specified in the CF. It particularly aims to promote reflection and cognitive dialogue in the learning context.

2.3.3. Implications for IMM courseware design and integration for learning

Fowler and Mayes' learning framework and Laurillard's CF offer a useful guidance in designing and integrating IMM courseware. Fowler and Mayes' learning framework specifies types of learning materials required for the three learning stages. In addition, it illustrates the role of dialogue in supporting the learning. The CF specifies the interactions and learning activities required for learning, which helps designing the interactions within and with IMM courseware in the learning context. A particular relevance of the two frameworks to this research is their emphasis on dialogue and reflection for learning, which this thesis aims to promote with IMM in a learning context.

These frameworks have been used in developing and assessing the design and integration approach, which will be presented in Chapter 4. In next section, a review of literature in the potential of IMM for learning will be presented.

2.4. Interactive Multimedia (IMM) for learning

There are several different definitions of multimedia, which has changed over time but in essence share a similar view. One of the early views of multimedia is : 'the use of different input devices and different media, both static media, text, graphics and images, and dynamic media, sound, video and animation in a system or service' (Clarke, 1992). This definition has changed to:

> 'A multimedia system is characterised by computer-controlled, integrated production, manipulation, presentation, storage, and communication of independent information which is encoded at least through a continuous (time-dependent) and a discrete (time-independent) medium.
>
> (Steinmetz & Nahrstedt,1995)

The latest one is:

> 'Multimedia is the combination of a variety of communication channels into a co-ordinated communicative experience for which an integrated cross-channel language of interpretation does not exist.'
>
> (Li & Drew, 2004)

The principal motivation or goal to use multimedia is to be informed or to inform someone else, to be served or to serve someone else, to be amused or entertained, and to teach or learn (EUSC, 1997). Non-linearity offered by multimedia allows the user greater navigational control, and information can be presented through different types of media. However, these features do not define the potential of multimedia or to justify its use. One of the strengths of multimedia is the integration of different media, which enhances information presentation (See 2.4.2). Second, the most significant strength of multimedia is interactivity that it offers. Interactivity does not simply mean easy information access or easy navigation in an IMM courseware. Interactivity offered by IMM should enable the learner actively engaged in the learning process. Particularly, effective interactivity enhances the interplay between internal and external learning processes (Rogers & Scaife, 1997). With its strong value of interactivity, easy navigational control, a large amount of available information and easy access to information, multimedia has much to offer for learning.

2.4.1. Strengths of IMM for learning

Multimedia with its combination of graphics, video, sound, animation and text has a number of potentially powerful characteristics which can be used to facilitate the learning process. First of all, by definition, it implies the use of combined media in presenting information which can be more effective than any single medium (Laurillard, 1993). The most appropriate medium for the required message can be selected, e.g. text for thoughts, graphics for spatial relations and animation for dynamic information. It also reinforces and supplements information through multiple representations, thus creating a redundancy effect.

Secondly, multimedia provides simulation and visualisation which are particularly useful in areas that require understanding of complex, abstract, dynamic and/or microscopic processes (Phillips, 1997). Moreover, multimedia allows users to take their own path through the material and to build up their own knowledge. Many studies have been carried out to investigate students' learning styles and their relevance to their learning outcomes (i.e. Riding, 1996; Pask, 1976; Kolb, 1984; Riding & Cheema, 1991). Combination of different media for the same information and possibility to access the content in a way desired (either linear or non-linear) can support students' different learning styles; as a result, a better learning outcome can be achieved. At the same time, it can encourage students to become more flexible in their mental processing by adopting different strategies (Phillips, 1997). Enriched context with static and dynamic media enhances learning with the above strengths; however, the essence of an educational multimedia application is good interactivity (McAteer & Shaw, 1995). It is the single most important strength of multimedia in education.

A. Interactivity

Interactivity is a key feature of successful multimedia. Interactivity is considered to be what defines the user's experience of a multimedia application (Feldman, 1994). Interactivity has different levels such as accessing information in a flexible and non-linear fashion by clicking a mouse to deeply engage the learner in cognitive tasks (Deegan et al., 1996). Rogers and Scaife (1997) define *interact* as referring to the various perceptual and cognitive processes that occur when external representations are used or constructed by the user in a given activity in their framework called external cognition. These include searching, parsing, recognising, abstracting, re-representing, remembering and keeping track of different stages of a problem or activity.

Interactivity supports learners to come to a deeper understanding through engaging the learner actively to construct knowledge interacting with IMM courseware. For example, in a virtual environment learners can manipulate virtual objects on screen and perform simulations of experiments. This allows the learner to experiment safely, enabling them to examine the consequences of taking wrong approaches as well as correct approaches and thus assisting the learner in coming to a deeper understanding of the subject matter (Boyle, 1997).

Care must be given when designing interactivity. While interactivity is expected to engage the learner in the learning process, some report opposites: 'Interactivity becomes too much like hard work and makes users switch off, mentally and physically' (Feldman, 1994). Much responsibility for learning and little guidance offered by IMM application could lead the learner to respond in this way (Laurillard, 2002). User control and interactivity at all levels should be carefully determined in terms of the user and the context in which it is used. Feldman (1994) puts it as: 'Multimedia is not about technology but people who will use it. Interactivity design must reflect this. '

In addition, in order to promote deep learning, IMM learning should be based on *active* interactivity which engages the learner in 'mathemagenic' activities, rather than on surface level such as clicking a button or dragging an object on screen and the computer responds to that action (Rogers & Scaif, 1997). They assert that appropriate external representation and cognitive tasks should be thoroughly planned and carried out based on sound pedagogy, and the nature of each media. In addition, the subject matter of which IMM aims to support learning and the learning context in which it will be used should be considered carefully.

B. Navigation, content structure and information representation

The ease with which the user can navigate through a system is vital to its overall level of usability (EUSC, 1997). Multimedia should be designed 'coherent' and 'easy' to use, and it should offer appropriate feedback or guidance to the learner (Cotton & Oliver, 1993). Care must be taken when designing content and navigation structures. First of all, it should allow users to control access to and navigation through information presented on individual screens in order to prevent disorientation (Chapman & Chapman, 2000). Secondly, the content and navigation structures affect the way students apprehend information structure, which is important for knowledge construction. Research shows that a significant minority of students experienced a lack of structure in an idealised multimedia system and that this affected their performance (Ford & Ford, 1992).

Laurillard (1993) also emphasises that the student should be able to focus on the content of learning, rather than the operation of the application. In order to achieve this, firstly, the content needs to be structured in a way which enables students to apprehend information structure easily. Secondly, how to access information required should be transparent and not require cognitive effort. Thirdly, balance between offering freedom to navigate and conveying the content structure intended has to be made carefully.

In terms of information representation, Mayer and Moreno (2002) compared learning effects between multimedia explanations with interesting details and ones containing only the core steps in the cause-and-effect chain. They found from the study that students learn more deeply from multimedia presentations that exclude extraneous words and sounds.

C. Choice of media

Researchers have conducted enormous studies comparing the teaching and learning effectiveness of various media, only to conclude that 'it depends' (Clark, 1995). Most of us have experienced ineffective instruction in various media, including the classroom and the computer. Any medium can be rendered ineffective by inappropriate methods. Therefore, in order to facilitate learning, media should be used as the means of implementing instructional methods which Clark (1995) identifies - demonstration, animation, examples, practice, and feedback, as well as conveying the material to be learnt.

Different media can be used to convey the same information in different ways, making use of redundancy in presentation, or to show information on different levels of abstraction (Scaife & Rogers, 1996; EUSC, 1997). Different media also have different qualities, which make them suitable for use in different situations and which determine their value within a multimedia application (EUSC, 1997).

There are several aspects considered in selecting media: the user, the content, the learning context (environment) in which the IMM courseware will be used and etc. First determinant criterion is the user. The knowledge and the experience of the user in the problem domain should be one criterion for the selection of the appropriate media. EUSC (1997) suggests that when the users know the problem domain well, a text-based presentation is often best suited. If the users happen to be new to the problem domain, graphical representations or spatial metaphors allowing for exploration are recommended. The age of the learner should also be taken into account. For children or elderly, graphical representations suits better.

Second criterion is the content. Media have to be determined depending on what they are to convey. This requires understanding of the strengths and weaknesses of each medium. To deliver abstract concepts or complex processes, graphical representation would suit better (i.e. England & Finny, 2002; Li & Drew, 2004; Cotton & Oliver, 1993). In general, visual presentation is claimed to offer better ways of facilitating cognitive tasks since people mostly perceive information through eyes (Clark, 1995). This includes the ideas that:

- static pictures and diagrams are better sentential representations
- three-dimensional representations are better than two-dimensional ones
- solid modelling is better than wire-frame modelling
- colour is better than black and white images
- animated diagrams are more effective than static images
- interactive graphics are better than non-interactive graphics
- virtual reality is better than animation.

(Scaife & Rogers, 1996)

Third criterion affecting the selection of media is its context. Where an IMM courseware will be used and how it will be used affect media selection: 1) where – in a lecture theatre, in a lab or at home; 2) how – independently or guided (presented) in lectures or tutorials. EUSC (1997) suggested the delivery as the fourth criterion is. In 1997, EUSC recommended to differentiate media selection depending on its delivery, for example, delivery between via the Internet and in a CD-ROM. This has been changed with the increasing capability of the Internet and technology available.

Another criterion is the requirement for the user to perceive the information presented by EUSC (1997). The memory of a user for facts varies according to the quality of the perception. An intensive experience enhances information recall, and the modality of information presentation and processing influence memory too. Although individuals differ in sensitivity to different modalities, the ease of memorable is from auditory, visual, audio-visual, thought about, to tried-out concepts. These criteria are applied for the interface and content design of IMM courseware developed for the empirical study.

Animation

Animation can be a very powerful tool for learning and with the increase in computer speed, complex animations have become practical. Many studies found that the use of animation improves performance on a learning task and provide guidance for animation design (i.e. Scaife & Rogers, 1997; Kuperberg, 2002; Thalmann, 1990). Active participation in the animation should be built in wherever possible.

England and Finny (2002) posit that parts of the animation which can respond to user input can reinforce the learning. Where the learning can involve action by the student, it will be more successful than a passive approach (Boyle, 1997). The involvement of the student in experimentation, decision making and hands-on manipulation is likely to aid the learning experience (EUSC, 1997). England and Finny (2002), Boyle (1997), and EUSC (1997) identify areas where animation is effective for:

- directing the user's attention to a specific point;
- visualising time and movement;
- showing an invisible process; e.g. an algorithm or a programme works;
- demonstrating something that would be too dangerous or difficult to perform directly;
- the exploration of complex environments;
- understanding of transformation;
- illustrating concepts or interface transitions;
- useful in developing analytical and discrimination skills;
- offering an ease of use with the look and feel changed;
- encouraging interest among young users in a learning programme.

Animation needs to be designed and integrated carefully as users can be easily distracted by other factors and the relevance of the animation is only partially understood (England & Finny, 2002). To keep the learner's attention to the animation, the remainder of the screen should be kept static. Also, limited use is advisable because it can be distracting when overused. The size should be no longer than 20 to 30 seconds at most (EUSC, 1997). England and Finny (2002) recommend three guidelines that are:

- animations are kept simple enough to be understood, but sufficiently complex to convey the important information;
- if too much happens at once : users fail to notice aspects – use cueing strategies;
- users should be given control of parts of the animation.

2.4.2. Media integration

The success of multimedia depends more on the chosen combination of media and its implementation rather than providing a set of media. EUSC (1997) provides general integrating media guidelines and they are as follows.

- All important auditory information is to be presented with visual form as well.
- Media for same information are to be linked together.
- Except summarising text, the exact words should be spoken.
- Synchronisation between the corresponding sequences is important.
- The constraints between multimedia objects should be specified in the following ways; time-based, object-based, or a combination of both.

More importantly, media should be integrated and presented considering cognitive effects. Scaife and Rogers (1996) propose three characteristics of external representation which we should consider - computational offloading, representation and graphical constraining.

- Computational offloading: This refers to the extent to which differential external representations reduce the amount of cognitive effort required to solve informationally equivalent problems.
- Re-representation: This refers to how different external representations, that have the same abstract structure, make problem solving easier or more difficult.
- Computational constraining: This refers to the way graphical elements in a graphical representation are able to constrain the kinds of inferences that can be made about the underlying represented world.

(Scaife & Rogers, 1996)

Others factors, such as the nature of the application, the environmental conditions, should be considered (EUSC, 1997) in addition to the ones mentioned above. In terms of IMM learning materials, this means that the subject matter, learning context and target audience should be taken into account.

When the same information is presented with multiple media and information access can be determined by the learner, not only will it produce redundancy effect but it also can support different learning styles. They will allow the learner to access information that can match their learning styles. Providing a summary or aims can guide the analytics to see a piece of information in the whole picture while supplying clear structure such as an overall menu depicting the content structure can lead the holists to understand the relations between various parts of information.

2.4.3. Multimedia design

Effective multimedia design means adopting a systematic and comprehensive approach to analysing the context of use such as looking at and modelling all the components and aspects involved (EUSC, 1997). Key factors to consider when assessing various designs include effectiveness, efficiency and satisfaction.

Elements of multimedia design

Based on the analysis of the nature of a multimedia application, the following elements should be designed:

- Content: Specify the information needs and interaction requirements of the users in the different tasks.
- Structure: Specify the structure between different pieces or chunks of information and how the user might gain access to this information.

- Access: Specify the information navigation and access techniques.
- Style: Specify the way each component of information will be presented to the user.

(EUSC, 1997)

The diagram below illustrates the different design elements.

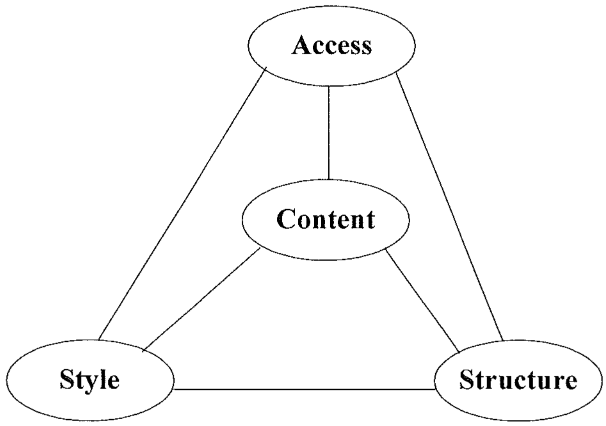


Figure 2-5 Multimedia Design Aspects (EUSC, 1997)

IMM learning materials should encourage students to focus not on the surface but on the content they learn. If the above four elements are not well designed and inter-linked together, IMM learning materials can not facilitate learning.

2.4.4. Integration into curriculum

As the number of students increases in higher education, it is inevitable that the learning process will be less and less well-supported by traditional teaching methods (Laurillard, 1995). Many studies on IMM assisted learning have been conducted in recognition of its potential for education and the need to bring technologies into higher education to facilitate learning. If IMM has a potential has to facilitate learning, why do many of IMM materials not promote deep learning? One reason among many is led by an assumption that IMM learning materials can empower students the control of their learning and students should take the control of their learning with them, which

Laurillard et al. (2000) and Laurillard (2002) argue strongly against. As another reason, Laurillard (2002) points out the emphasis on the development and use of technology rather than research and evaluation by most of the studies.

To facilitate learning in higher education, not only do we need good educational material but we also need to use them in a way that students can learn from them. Soper (1997) argues that effective use of these IMM materials requires that they should be integrated into the course and that students have appropriate support and guidance. Emphasising the importance of integration, Feldman (1994) puts it: 'multimedia does not indeed cannot, exist in isolation.'

Learning in higher education depends on the whole teaching and learning environment (Prosser & Trigwell, 1999). When students have heavy workload, it has a negative effect on learning (Ramsden, 1992; Prosser & Trigwell, 1999). Students may neither pay due attention to multimedia courseware nor able to spend sufficient time on it if it is not fully integrated into their course. Laurillard (2002) reasons the need for full integration as:

> ' … a fully integrated part of everyday academic life because students respond primarily to the institutional context and its demands, so these must be congruent with the demands of the technology. … Full integration is vital for optimising any investment in learning technology.'

The design of an effective IMM learning material is important to facilitate learning in higher education. Nevertheless, its effective integration into the curriculum and the learning environment that enables students to use the IMM materials are crucial. IMM materials delivered with appropriate supports from a tutor will improve student learning experience. Soper (1997) has used a workbook which complemented 'WinEcon Software' to help individuals achieve their learning goals and ensure they get the maximum benefit from the screens. One of the findings from the study is that a combination of materials that offer flexibility in use can support a variety of different learning needs.

After pointing out lack of research and evaluation of the studies into technology-assisted learning as one of main reasons that cause ineffective learning use of the technology in the context, Laurillard (2002) asserts that: 'we should be building a body of knowledge of how best to use learning media, and creating a teaching profession that knows what it is doing and why.' Further research is required to explore effective ways to use IMM to facilitate student learning into higher education, to which this thesis aims to make a contribution.

CHAPTER 3 PRELIMINARY STUDY: TEACHING AND LEARNING OF PROGRAMMING IN PRACTICE

The primary aim of this research was to find a way to facilitate teaching and learning of programming. As described in Section 1.1, IMM has the potential to support the teaching and learning process of programming, particularly introductory programming to first and second year students. To investigate the difficulties of teaching programming and to explore the potential of IMM for the subject matter, a preliminary study was conducted at two UK Universities. The findings from this study helped develop the design and integration approach, which will be presented in Chapter 4.

This chapter reports the results of the preliminary study at Napier and Brunel Universities. Teaching and learning of two particular programming modules, the Software Development 1B at Napier University and Object-Oriented Programming module at Brunel University were investigated with an additional objective. An empirical study for this research was planned with these modules at the two universities. This required analysing the needs and identifying the requirements for IMM courseware.

Questionnaires with students, and interviews with lecturers were conducted at both universities. Their existing course materials were assessed. Analysing the data in this study yielded useful information in four areas: difficulties of teaching and learning of programming, possible benefits of integrating IMM courseware into the curriculum, usability issues, and useful design features for programming. These informed how IMM courseware should and could be used to facilitate student learning of the subject matter.

Section 3.1 presents the aims of this study. Having described the rationale behind the choice of the two UK universities and the teaching situations with the programming modules in Section 3.2 and Section 3.3, the methods used follow in Section 3.4. The results are reported in Section 3.5, and this study is summarised in Section 3.6 identifying the requirements for IMM courseware design and integration.

3.1. Aims of the study

As mentioned in the beginning of this chapter, this study had two purposes. One was to further investigate difficulties in teaching programming. The second was to do needs analyse for IMM courseware for programming modules at Napier and Brunel universities, which will be described in Section 3.3. As will be described in Section 3.2, case studies will be conducted at Napier and Brunel universities. For the studies IMM courseware will be designed by the author in collaboration with the lecturers at the universities. Therefore, this study aimed to identify the needs and requirements for IMM courseware for the programming modules.

The aims of this study were:

- to investigate difficulties of teaching and learning of programming;
- to identify design features suitable for the domain from analysing the existing course materials at both universities;
- to identify benefits and weakness of the existing materials;

3.2. Rationale for the study at Napier & Brunel Universities

This study investigated teaching and learning of two introductory programming modules at Napier and Brunel universities: Software Development (SD) 1B at Napier University, and Object-Oriented Programming (OOP) module at Brunel University. As discussed in Section 1.1, introductory programming is difficult to teach and to learn with two main reasons. One reason is the complex and abstract nature of the domains (Dermot, 1995). The other is the diversity of students in background knowledge and interests in the subject matter.

Like many other universities, both Napier and Brunel universities had encountered difficulties in teaching these introductory programming modules to a large number of students and had sought a means to improve their teaching and learning situations. As a solution, two lecturers at both universities had developed course materials with visualisation and used them in lectures to support teaching and learning with their programming modules. As discussed in Section 1.1, visualisation can be effective in supporting abstract concepts of the domain (i.e. England & Finny, 2002; Boyle, 1997; Shinners-Kennedy, 1995).

At the time of this study, the lecturers at both universities were interested in using IMM for their modules. However, the idea was not materialised yet due to insufficient resources and their limited knowledge in IMM design and development. The lecturers' desire to use IMM courseware for their modules met the author's needs to conduct this research in classroom settings.

3.3. Teaching and learning situations with two programming modules

This section presents the teaching situations with two programming modules at Napier and Brunel universities. Brief descriptions of the modules, teaching situations and teaching strategies used will be described.

3.3.1. Teaching introductory programming modules at Napier University

Module description

The School of Computing at Napier University offers two introductory programming modules to 1st year Computing and Engineering courses: the Software Development (SD) 1A in semester 1 and the Software Development (SD) 1B in semester 2. They are companion modules; the first is the prerequisite of the latter. The SD 1A module is designed to teach fundamental programming with C++/Java (The programming language used for this module changed from C++ to Java from 2000/2001 academic year), and the SD 1B is to teach object-oriented development. These modules aim to support students to gain a good foundational understanding of programming. Each year a large number of students (approximately 200) enrol for these modules. As the students are from various Computing and Engineering courses (14 courses in 1999/2000), they have diverse background knowledge and interests in the domain.

Teaching situations and teaching strategies used for the SD 1B module

The lecturer, the module leader of these introductory programming modules, had experienced difficulties in teaching and supporting the number of students in and out of a lecture theatre. Another challenge was to teach students the object-oriented development *process.* As discussed in Section 1.1, many students in introductory programming modules tend to focus on the programming stage instead of the programming processes. In addition, the lecturer tried to support students to acquire problem-solving skills. During interviews, the lecturer emphasised industrial demands for problem solving skills and the needs to provide a teaching and learning environment in which students could acquire those skills. This was one of the main reasons that motivated the lecturer to seek ways of supporting and encouraging independent learning with the module.

For the past several years, he had used three approaches to support students' learning with the SD 1B module. In phase 1, he had used electronic course materials with visualisation as a teaching aid in lectures and learning materials. These materials were called Toolbooks as they were developed in an authoring tool named Toolbook (SumTotal). These electronic materials (Toolbooks) contained visually enhanced information for object-oriented concepts and design, and programming with C++.

In phase 2, in addition to using Toolbooks, the module leader co-authored a paper-based booklet to support students' learning. This booklet contained detailed information of object-oriented development processes with UML, step-by-step examples and tasks. In phase 3, the lecturer had used a modelling environment, called ROME (Wheeler, D. 1998), to help students design and develop object-oriented systems. The modelling tool, developed at Napier University, displayed dynamic linking between a class diagram and its programme. Students could start designing a system using Unified Modelling Language (UML) in ROME with either a collaboration diagram or a class diagram. In ROME, students could create one diagram from the other one automatically. When they change one diagram, the change would also appear in the other. Furthermore, ROME could automatically generate C++ or Java programming from a class diagram. Students could see them both (design and programming) in two separate windows. Just like changes in either collaboration diagrams or the class diagram automatically appeared in the other, changes in either the class diagram or its programme would automatically reflect in the other.

The primary aims of the three interventions were 1) to encourage students to approach programming processes holistically; 2) to help students gain a good understanding of object-oriented design and programming with Toolbooks and then build their knowledge with the booklet and ROME.

Module delivery

The SD 1B module was composed of weekly lectures and tutorials. In lectures Toolbooks were used to visually enhance teaching. In tutorials, students did practical design and programming tasks with ROME and C++ compiler. When this study was conducted, the module leader (*Lecturer N*) was in the process of re-designing Toolbooks in Authorware for three reasons. The first was that the programming language taught in the SD 1A and SD 1B had changed from C++ to Java from 2000/2001 academic year. Secondly, there was a need to improve the usability of Toolbooks in order to better support independent learning. Thirdly, there were more available authoring tools such as Macromedia Authorware, Director and so on.

3.3.2. Teaching introductory programming modules at Brunel University

Module description

The department of Electronic & Computer Engineering at Brunel University offers many programming modules to a large number of 1st and 2nd students from various Computing-related and Engineering courses. In 2000/2001, the Object-Oriented Programming (OOP) module was offered to 2nd year students in semester 1. The OOP module aimed to teach both procedural and object-oriented programming with C++. For the module, advanced programming concepts were taught, and the students who enrolled for this module were expected to have a fundamental understanding of programming with C++ as it was offered in second year. From 2001/2002, this module was restructured to the Object-Oriented Software Design (OOSD) and Object-Oriented Programming Workshop (OOPW) modules, which were designed to teach object-oriented design and programming with C++.

Teaching and learning situations with the module and teaching methods used

The module leader (*Lecturer B)* said that many students had had an insufficient understanding of programming to proceed to learn the advanced programming concepts from the module although they had passed their 1st year programming modules. Some students had not gained a fundamental understanding of programming concepts in their first year, and the others students were direct-entry to 2nd year. The module leader cited that the students' diverse background knowledge levels had brought difficulties in classroom teaching as well as supporting students' independent learning outside the classroom.

With conventional paper-based teaching in lectures and practical programming work in tutorials (lab sessions), many students had showed difficulties in learning the subject matter. When students were doing practical programming tasks in tutorials, many had asked their tutor for help without trying to find solutions by themselves first. As a result, students asked the same questions to their tutor repeatedly. In worse cases, some students gave up doing the tasks even without seeking help from their tutors.

To solve this problem, *Lecturer B* had decided to develop and use course materials with visualisation to assist teaching in lectures and to encourage students' independent learning. *Lecturer B* had developed Flash animations and embedded them in PowerPoint slides. The animations illustrated programming concepts with real life objects. It was realised that although the use of the PowerPoint slides with Flash animations helped students understand programming concepts in lectures, they supported students' learning not as much as *Lecturer B* had expected.

Module delivery

The OOP module was delivered by weekly lectures and one tutorial every two weeks tutorials. In lectures, programming concepts with C++ were taught and in tutorials students did practical programming tasks with a DOS-based C++ compiler.

Lecturer B was interested in using IMM courseware to better support independent learning, yet the same reasons at Napier University diminished its possibility (*Lecturer B* preferred to design her own IMM courseware rather than using a commercial product). *Lecturer B* and the author planned to develop IMM courseware for the C++ Programming & Software Design 2 module, for which she was the module leader and was going to be delivering it in the following semester to 1st year students.

3.4. Methods

Interviews with lecturers and two questionnaire surveys with students were performed. Also, the usability of Toolbooks at Napier University and the PowerPoint files at Brunel University were assessed. The research methods used and their aims are summarised Table 3-1 and Table 3-2.

Institution	**Napier University**	**Brunel University**
Module	Software Development 1B	C++ Programming & Software Design 2
Semester	Second semester of first year	First semester of second year
Method	▪ A questionnaire with students ▪ Interviews with the lecturer ▪ Assessment of the existing course materials (Toolbooks) ▪ Assessment of students' performance	▪ A questionnaire with students ▪ Interviews with the lecturer ▪ Assessment of the existing course materials (PowerPoint with Flash animation embedded) ▪ Observation during two three hour tutorials

Table 3-1 Summary of research methods used for the study

Method	**Aims**
Questionnaire	To explore students' learning experiences with the subject matter and the course materials used.
Interview with lecturers	To explore lecturers' teaching experiences with the subject matter; To explore their experiences in designing and using the existing electronic course materials; To ascertain other activities involved in learning and teaching;
Existing courseware assessment	To identify strengths and weaknesses of the electronic materials; To determine the role the materials played among course materials.
Assessment of students' performance at Napier University	To explore relationships between students' performance and perceptions. To investigate how Toolbooks affected students' performance as well as perceptions of the subject matter.

Table 3-2 Aims of each method

A. Interviews with *Lecturer N* and *Lecturer B*

Initially interviews with *Lecturer N* and *Lecturer B* were conducted as part of the needs analysis and later as part of the design and development processes of IMM courseware for their modules. With *Lecturer N*, weekly interviews (meetings) were conducted from September 2000 until February 2001, and occasional meetings were arranged to discuss during case study 1 (from February until June 2001). With *Lecturer B*, mostly phone calls and e-mail correspondences were used due to the distance. In addition, long interviews (meetings) were carried out during the author's visits to Brunel University. As a pilot study and two case studies, as will be reported in Chapter 5, Chapter 7 and Chapter 8, were conducted at Brunel University, the correspondences and interviews with *Lecturer B* continued from October 2000 until February 2002. The topics discussed during the interviews with both lecturers were:

- the difficulties of teaching the module and of supporting student learning with the modules;
- the benefits and weaknesses of Toolbooks / the PowerPoint with Flash animations (existing course materials at the universities) for student learning with the modules from the lecturers' teaching experiences;
- the areas where IMM courseware was required to support in the teaching and learning contexts (how and what area both lecturers considered IMM courseware needed to help in the contexts);
- the integration methods of IMM courseware into the curriculum and the design features and architecture of the courseware;
- design and development processes of IMM courseware (delivery schedules and who were going to prepare the content and etc.).

B. Questionnaires

Two questionnaire surveys, included in Appendix 1 and 4, were conducted at Napier and Brunel universities to ascertain students' learning experience with the modules and the existing course materials: Toolbooks for the SD 1B module at Napier University and the PowerPoint slides with Flash animations for the OOP module at Brunel University.

The questionnaires were aimed:

- to explore how the students perceived and used the existing course materials;
- to identify the benefits and weaknesses of the course materials;
- to explore what the students considered most difficult to learn from the subject matter.

Questionnaire at Napier University

A questionnaire was answered during a lecture of Software Development 2A module in week 2 of 2000/2001 academic year. The questionnaire was designed by the author in collaboration with *Lecturer N.* The students, who participated in the questionnaire, had taken the SD 1B module in the previous semester and had used Toolbooks as part of course materials. The module leader was one of the teaching team for the SD 1B module and explained the purpose of the questionnaire. Seventy one students participated in the questionnaire.

Questionnaire at Brunel University

In week 10 of 2000/2001 academic year, a questionnaire was answered by the students enrolled for the OOP module. This was conducted during the pilot study, and at the time of this study the students were using the PowerPoint slides with Flash animations embedded as their course materials. Among 23 students who enrolled for the module, 19 participated in the questionnaire.

C. Usability assessment of the existing materials

Toolbooks and PowerPoint slides were assessed. The primary aims were:

- to assess the usability of the materials in the teaching and learning contexts;
- to examine the design features used for the subject matter.

D. Observation at Brunel University

During the pilot study, as will be reported in Chapter 5, observations were conducted during two 3 hours tutorials. The purpose was to observe students' learning activities in tutorials (practical sessions), i.e. their approaches' to programming tasks, their interactions with their peers and teaching staff, and their use of course materials and etc.

3.5. Results

Section 3.5.1 will report the usability assessment results of Toolbooks and PowerPoint slides at the two universities. After presenting the results from the interviews with *Lecturer N* and *Lecturer B* in Section 3.5.2, the results from the questionnaire survey at Napier will be reported in Section 3.5.3.

3.5.1. Evaluation of the electronic materials at Napier and Brunel Universities

Toolbooks at Napier University and the PowerPoint at Brunel University were assessed in terms of the architecture, content structure, information representation, interface and navigation. The results will be summarised briefly; the assessment results are included in Appendix 2. The assessment of both Toolbooks and PowerPoint materials revealed some usability problems that needed to be improved. Particular problematic areas were navigation and interface design.

- Navigation: Both Toolbooks and PowerPoint materials consisted of several files with no opportunity to navigate between them. In each Toolbook or PowerPoint file, only linear navigation was provided. In addition, random access was not available as there was no main menu page in both materials.
- Interface design: Both Toolbooks and PowerPoint required much improvement for the interface. As for Toolbooks, the screen size and text size required to be bigger for both when using them in lectures and learning. For PowerPoint materials, an interface with consistency was to be used. As described in Appendix 2, the colours used in both needed to be improved.

In addition to the two main usability problems, there were other areas to be improved, such as help and search facilities to support learning, of which both lecturers revealed that they were aware of most problems, but the problems were not remedied due to their insufficient knowledge or techniques in IMM courseware design and development.

3.5.2. Results from interviews with lecturers at Napier and Brunel Universities

Lecturer N and *Lecturer B* had developed Toolbooks and the PowerPoint slides with animations and had used them for teaching and supporting student learning of introductory programming modules. Their experiences provided valuable information in developing the design and integration approach suitable for programming which is presented in Chapter 4.

Results from the interviews with lecturers are reported in 1) the difficulties they had experienced with the modules; 2) the strengths and weakness of Toolbooks and the PowerPoint materials; and 3) the needs for IMM courseware for the modules.

A. Difficulties from teaching the modules and supporting student learning

Difficulties at Napier University

Two main difficulties of teaching and supporting learning of the SD 1B module were identified and they were as follows:

- students' 'surface' approaches to learning the programming process;
- learning support for a large number and diversity of students.

As mentioned in Section 1.1, many students in introductory programming modules tend to focus on programming (coding) aspects instead of the whole programming process, which Marton and Booth (1997) identify as a 'surface' approach to learning programming. It was revealed from the interviews with *lecturer N* that a large number of students taking the programming modules at Napier University adopted 'surface' approaches to learning the subject matter.

Difficulties at Brunel University

The difficulties *Lecturer B* had experienced from teaching the OOP module are listed below:

- the complex and abstract nature of the subject matter;
- vast differences in students' background knowledge with the subject matter;
- some students' poor mathematical knowledge.

As for the first, it is a general problem with the subject matter. As for the second, *Lecturer B* reasoned that the gap between students' knowledge of programming became wider from the first year programming modules. Whereas some students had obtained a good understanding of programming, the others simply passed the modules without gaining a sufficient understanding to continue programming modules in their second year.

Byrne (2001) reports, from investigating the relationship between Mathematics aptitude and student learning with programming, that there is a significant relationship between Mathematics points and programming examination scores. *Lecturer B* perceived that some students' difficulties of learning programming at Brunel University were caused by their insufficient knowledge in Mathematics.

B. Strengths and weaknesses of Toolbooks and PowerPoint slides

The strengths and weaknesses of the electronic materials (Toolbooks & PowerPoint slides) at Napier and Brunel Universities, identified by the lecturers at the universities, were similar, and they were presented together.

Strengths of Toolbooks and the PowerPoint slides

The strengths of the materials, *Lecturer N* and *Lecturer B* identified from their teaching experiences, were listed below.

- Use of the materials in lectures and for learning
- Information representation
- Animation design
- Content structure of Toolbooks

Both considered using the materials in lectures and for learning beneficial. The materials facilitated student learning in three ways. One was that it had helped students' understanding in lectures. The second was that the materials helped students' independent learning. The third was that using the materials in lectures encouraged the students to use them for learning. *Lecturer B* asserted that students had been likely to be inclined to try to use the PowerPoint slides for learning because they had been introduced in lectures.

As for the second, both lecturers considered presenting information with animations and text had been effective in supporting lectures and independent learning. As for the third, both perceived that the animation had helped students understand the concepts. As for the fourth, content structure at Napier University, *Lecturer N* considered that the structure of the content had helped students grasp the meaning of a concept.

Weaknesses of Toolbooks and the PowerPoint slides

From interviews with the lecturers similar the weaknesses of Toolbooks and the PowerPoint slides were identified, and they were as follows:

- Independent learning supports
- Usability
- Interface design
- Tasks

Both lecturers considered that the materials needed to be improved in order to support independent learning better. As for the usability and interface design of the materials, they cited that much improvement was required to support learning. The last topic, tasks, was identified during the interviews with the author. Although the materials at both universities presented visually enhanced programming concepts, they did not have any tasks for students to test their understanding of the concepts

C. Requirements identified for IMM courseware at Napier and Brunel universities

The requirements identified for IMM courseware for the modules at the universities were that it should;

- support independent learning as well as assist teaching in lectures;
- encourage students to use it for learning; have a good usability and friendly interface;
- provide interactive tasks with which students can test and apply their understanding;
- support students to continue to learn advanced programming concepts at the same time help them fill their knowledge gap (Brunel).

3.5.3. Results from questionnaire study with students at Napier University

The results from the questionnaire with students at Napier University are reported in the following areas: students' perceptions with the subject matter and their understanding of it; the benefits and weaknesses of Toolbooks they perceived in the learning context; and their use of Toolbooks for learning.

Students' perception with and understanding of the subject matter

Two questions were asked to investigate how students perceived the subject matter and their understanding with it. As Figure 3-1 shows, 31% (22/71) of the students replied that the subject matter was difficult to understand. Only 15% (11/71) considered it easy.

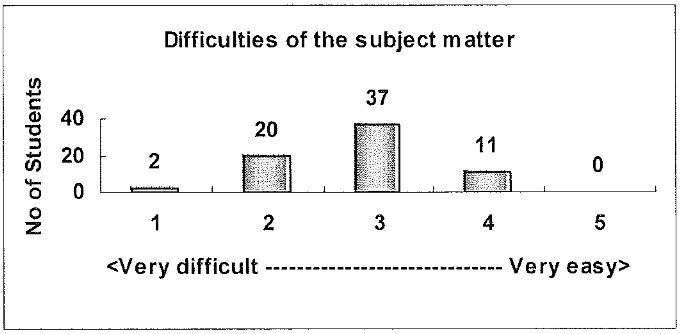


Figure 3-1 Students' self-rated difficulties of software development concepts (n=70, missing=1)

However, the students responded more positively for the question about their understanding of the subject matter. As illustrated in Figure 3-2, only 14% (9/71) considered their understanding poor, and 40% (29/71) perceived their understanding good. Overall, the students' responses about their understanding were more positive than their perceptions of the subject matter.

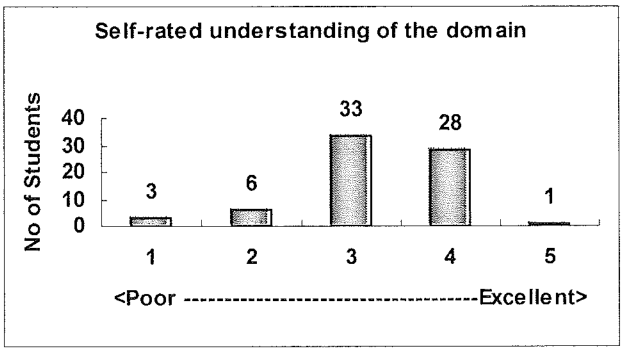


Figure 3-2 Students' self-rated understanding of software development concepts

It was interesting to explore whether the students' rating of their understanding of the subject matter was related to their perceptions of the difficulty/ease of it. Students' responses between them are presented in Table 3-3. There were some students (6), who perceived the subject matter difficult (grade 2) but considered their understanding of it good (grade 4). About 6 students considered the subject matter easy to understand but their understanding rather poor. However, most students' perceptions of the subject matter seem to reflect in their understanding of it.

		Students' understanding of the domain					
		1:Poor	2	3	4	5:Excellent	Total
Students' perceptions of the domain	1:Very difficult						
	2		2	3	6		11
	3	2	1	18	15	1	37
	4	1	2	10	7		20
	5:Very easy		1	1			2
	Total	3	6	32	28	1	70

Table 3-3 Students' perceptions of subject and their understanding (n=70, missing=1)

A. Students' experiences and perceptions of Toolbooks

Use of Toolbooks

Use of Toolbooks—when used

For the question about 'when did you use Toolbooks', 44% (31/71) responded that they used Toolbooks initially all the time and then less as their understanding improved, and 27% (19/71) answered that they used the materials more later as they found their understanding insufficient. Figure 3-3 shows that 15% (11/71) of the students never used the materials outside the lecture theatre.

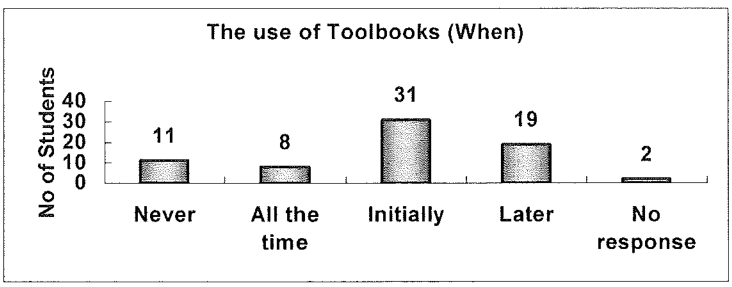


Figure 3-3 When students used Toolbooks

Use of Toolbooks—How used

A question was asked to explore how students used Toolbooks for learning. The majority of students (60%) used Toolbooks as reference materials to look up a topic, and 21% (15/71) used the materials as main resources.

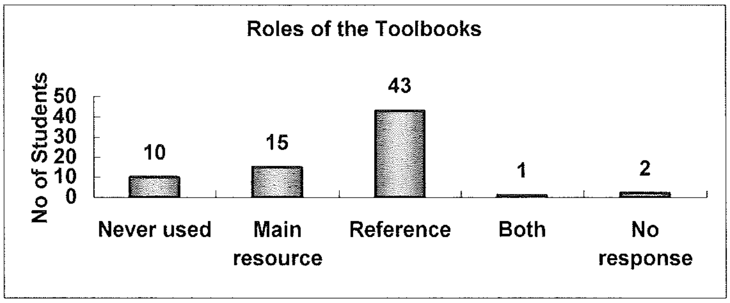


Figure 3-4 How students used Toolbooks

Students' responses to this question suggest three possible reasons. One is that they may have considered Toolbooks easy to find information. The second is that they may have considered the materials provided good descriptions of programming concepts. The third is that they may have used the materials because it was available on the university Intranet all the time.

B. Learning support from Toolbooks

Toolbooks in assisting to the understanding of abstract concepts & visualisation

Question 11 was asked to ascertain how much students considered Toolbooks had helped their understanding of the abstract programming concepts. As illustrated in Figure 3-5, 63% (45/71) of the students cited that Toolbooks helped their understanding of abstract object-oriented concepts.

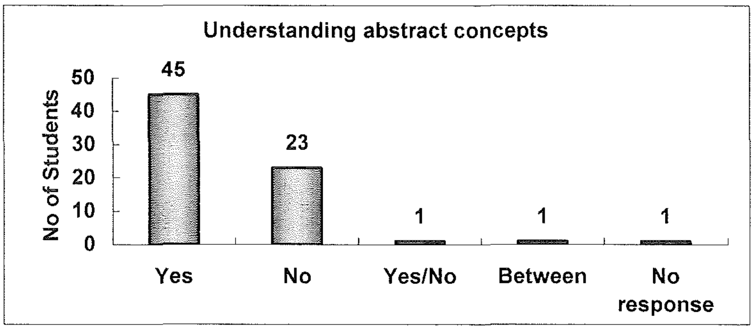


Figure 3-5 Toolbooks helping understand the abstract concepts[1]

To determine to what extent the visualisation in Toolbooks had contributed to the students' understanding of the concepts, Question 13 (how much the visualisation assisted your understanding for the concepts) was asked. As displayed in Figure 3-6, students' responses from the question were more positive than their responses from Question 11.

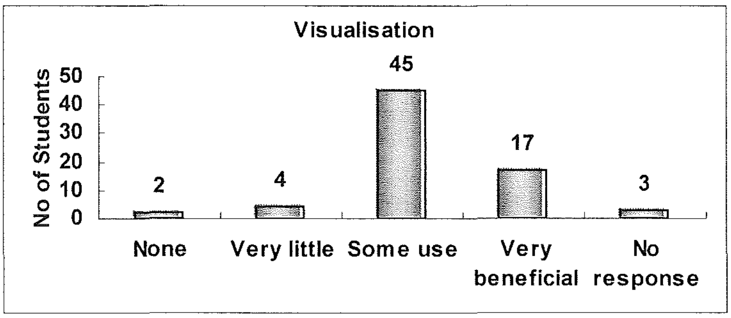


Figure 3-6 Visualisation

Whereas 63% considered that Toolbooks helped their understanding of the abstract concepts, 87% (62/71) of the students responded that visualisation helped their understanding of the concepts. The increase in students' responses for visualisation helping their learning than for Toolbook helping their learning suggests an inconsistency in their perceptions of Toolbooks. Some students responded for Question 11 that Toolbooks did not help their understanding of the abstract concepts. But at the same time they considered the visualisation in Toolbooks helped their understanding to a certain extent.

[1] The reason for the answer "Between" was "There are just some things I grasp and some things I don't".

As described in Section 3.3.1, the primary reason that *Lecturer N* had designed and used Toolbooks had been to help students understand abstract object-oriented concepts, and visualisation was the main feature used to achieve it. The students' responses for Question 13 about 'visualisation helping their understanding of the concepts' suggest two things. One is the effectiveness of visualisation for the subject matter. The second is that the visualisation design in Toolbooks was effective for students' understanding.

To further examine the inconsistency in the students' responses from Question 11 and Question 13, their responses between the questions were compared. The results are presented in Table 3-4.

	Visualisation helped understanding				
	None	**Very little**	**Some use**	**Very useful**	**Total**
Toolbooks helped		2	27	15	**44**
Toolbooks did NOT help	2	2	16	2	**22**
Total	**2**	**4**	**43**	**17**	**66**

Table 3-4 Toolbooks' help with understanding abstract concepts vs. visualisation helping understanding (no response = 5)

As presented in Table 3-4, some students' responses were contradictory. Twenty two students did not consider that Toolbooks helped them understand the abstract concepts. However, 18 out of 22 students responded that visualisation helped understand the concepts. This result raises a question: 'What caused the students to consider that visualisation in Toolbooks helped their understanding of the object-oriented concepts and at the same time they did not consider Toolbooks themselves helped their understanding of the concepts?' Data was further analysed to explore if the way students used Toolbooks were related to their perceptions of Toolbooks and the visualisation in them helping their understanding.

Before reporting the results, students' responses to 'how visualisation helped their understanding' are summarised. Mostly students cited that the visualisation in

Toolbooks had eased and helped their learning in three areas:

- helped understanding concepts (16 students);
- clarified textual explanation (2 students);
- helped understand how the concepts work in programming (4 students).

Following are some of students' comments.

> *N00S1*: Gave a visual illustration of what was being explained, so eased learning...
> *N00S2*: Through the use of diagrams they make the concepts a little easier to understand...
> *N00S3:* Made me aware of message passing ideas. Only in Lecturer B's lectures..."

Excerpt 3-1 Students' comments on visualisation help in Toolbooks

Visualisation and use of Toolbooks

Students' use of Toolbooks was compared with their responses to Question 13 (the visualisation helping their understanding). The results are summarised in Table 3-5.

	Visualisation				
	None	**Very little**	**Some use**	**Very useful**	**Total**
Never used Toolbooks			<u>*10*</u>		
All the time		1	3	2	**6**
Initially	1	1	20	9	**31**
More later	1	2	11	5	**19**
Total	**2**	**4**	**44**	**16**	**66**

Table 3-5 Visualisation helping understanding vs. students' use of Toolbooks (no response = 5)

An interesting thing to note in Table 3-5 is that 10 students who did not use Toolbooks for learning, but they considered visualisation useful (some use), which suggests that these students could have considered the visualisation in lectures beneficial. When the students' responses were further examined, it was found that among the 10 students, underlined in Table 3-5, 7 students cited that Toolbooks did not help them understand the abstract concepts. This partly explains the students' contradictory responses between the help from Toolbooks and the visualisation for understanding the concepts.

Learning support from Toolbooks vs. use of Toolbooks

The contradictory responses between the help from Toolbooks and the visualisation were partly explained from their use, or no use, of Toolbooks for learning. The rest can be explained by their approaches to use them for learning. As Table 3-6 shows, the students who had used Toolbooks as main resources responded more negatively than ones who had used as reference materials.

	Toolbooks use			
	Never used	Main resources	Reference materials	Total
Toolbooks helped	3 (30%)	9 (56%)	31 (78%)	43 (65%)
Toolbooks NOT helped	7 (70%)	7 (44%)	9 (22%)	23 (35%)
Total	10 (15%)	16 (24%)	40 (61%)	66

Table 3-6 Students' approaches to using Toolbooks vs. their perceptions of Toolbooks helping understanding (no responses = 5)

In addition, the students, who had used Toolbooks all the time or later, had poorer opinions of Toolbooks, as displayed in Table 3-7 .

	Use of Toolbooks (when)				
	Never	All the time	Initially	More later	Total
Toolbooks helped	3 (27%)	5 (71%)	23 (77%)	12 (67%)	43 (65%)
Toolbooks NOT helped	8 (73%)	2 (29%)	7 (23%)	6 (33%)	23 (35%)
Total	11 (17%)	7 (11%)	30 (45%)	18 (27%)	66

Table 3-7 Students' responses between Toolbooks' help vs. when Toolbooks used

Primarily, Toolbooks were designed to assist teaching and provide clear yet brief information of the subject matter. As main resources, Toolbooks may not support learning sufficiently. As for the students who answered that 'Toolbooks had not helped their understanding' and 'had used the materials more later', their responses could be caused by ease/difficulty of finding a topic (the usability). When students' responses for

Question 14 (how easy/difficult to find a topic in Toolbooks) (see Figure 3-12) were examined, it was revealed that the students who had used Toolbooks later considered 'finding a topic' more difficult than others.

Strengths of Toolbooks

For Question 11 about 'Toolbooks help for understanding' and Question 13 about 'visualisation help for understanding', students were asked to give explanations of how they had been helped. For Question 11, 42 students gave their reasons and as for Question 11, 21 students explained how visualisation had helped their understanding. In addition, many students gave comments about Toolbooks. The learning supports from Toolbooks in their learning context that the students identified are summarised as follows:

- Toolbooks in the learning context had supported students to recall the lecturer's explanation during the lectures when they had been learning with the materials;
- it had corrected their misunderstanding;
- it had clarified the meaning of object-oriented concepts;
- it had provided information missed in lectures;
- it had enhanced the meaning of text information or the lecturer's description in lectures.

To determine how Toolbooks in the learning and teaching context had helped students' learning of the subject matter, students' responses were categorised. Qualitative data analysis methods from Dey (1993), and Bryman and Burgess (1994) were used to analyse the data. From analysing students' answers from Question 11, Question 13 and their comments, the benefits of Toolbooks were classified into three categories: 1) learning supports by the use in the context; 2) learning supports from the content design; and 3) learning supports as independent learning materials. The three categories classified into several sub-categories. The learning supports by the use in the context are illustrated in Figure 3-7 .

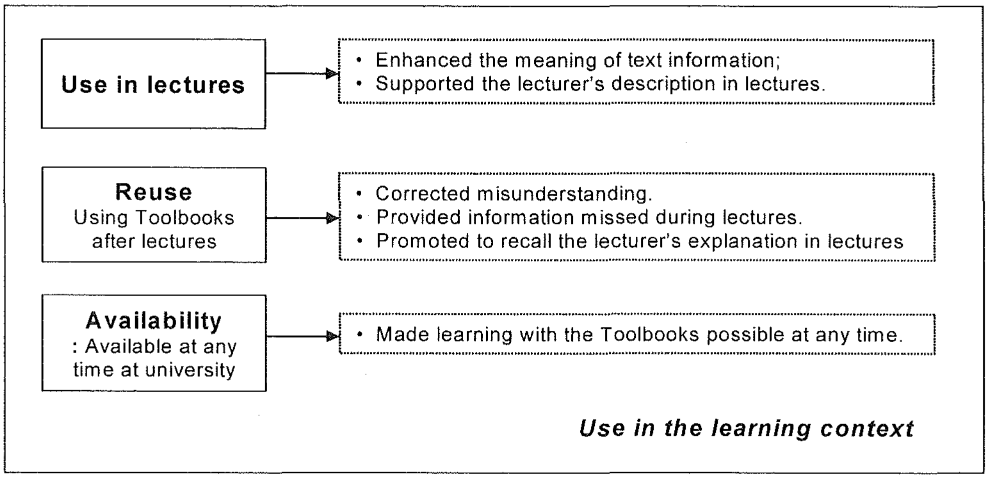


Figure 3-7 Learning supports by the use of Toolbooks in the learning context

As displayed in Figure 3-7 , the learning supports, from the use of Toolbooks in the context (using them for teaching and learning), were all of the five listed above. These results reveal benefits of integrating IMM courseware for both teaching and learning. Figure 3-8 illustrates the learning supports from the content design with its sub-categories and how they were related to students' learning of the subject matter.

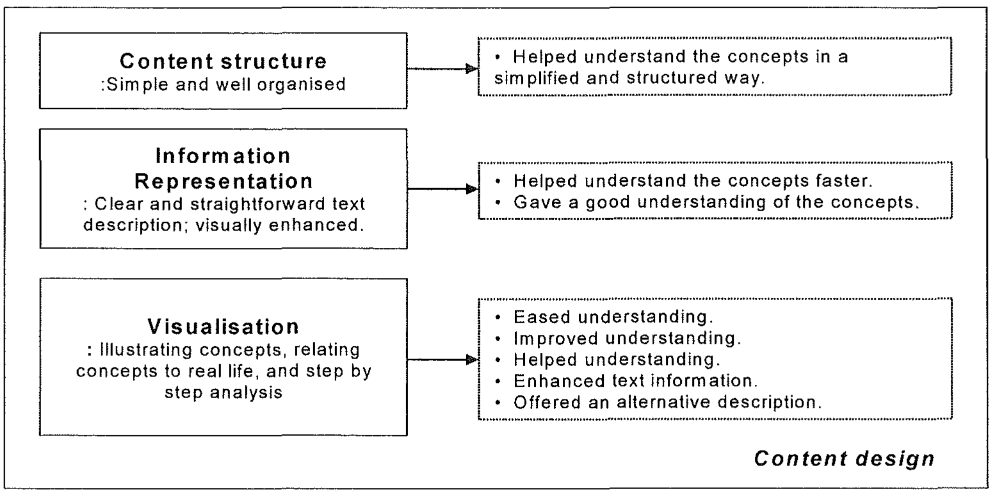


Figure 3-8 Learning supports from the content design of Toolbooks

The learning supports from the content design were that information was structured and presented in a simple, clear and precise manner. Visualisation had illustrated object-oriented concepts step by step, and the text presented information in clear and straightforward way. Both helped students understand the object-oriented concepts. In addition, visualisation had offered an alternative description of a concept.

As for the third category, the learning support of Toolbooks as an independent learning material, the benefits offered were that:

- they provided a useful learning tool;
- they offered an easy learning environment;
- students were able to use them as much as needed.

C. Role of Toolbooks

Future use of Toolbooks: a teaching aid and independent learning

For the question about 'how they perceived Toolbooks', 89% (63/71) of the students considered that Toolbooks should be used both as a teaching aid and as independent learning materials.

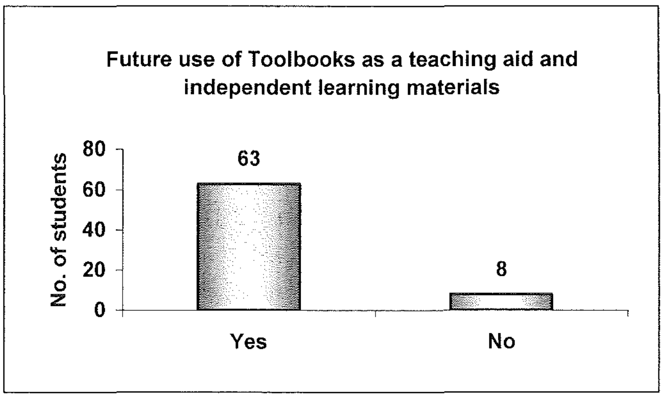


Figure 3-9 Students' perceptions of Toolbooks as a teaching aid and independent learning materials

Personal preferences to paper-based learning were identified as a reason for the students who did not think Toolbooks should be both a teaching aid and independent learning materials. Examples of their replies were:

> *N00S4:* Prefer paper copy and lecturers there to clarify misunderstanding.
> *N00S5*: I would rather have a paper copy.
> *N00S6*: Many people do understand better when listening and reading.

Excerpt 3-2 Students' comments on their preference of paper-based learning

Role of Toolbooks: teaching aid or learning materials

About the question about 'the role of Toolbooks', 62% (44/71) of the students perceived the materials as learning materials, and 31% (22/71) considered them as a teaching aid. Additionally, 5 students chose both.

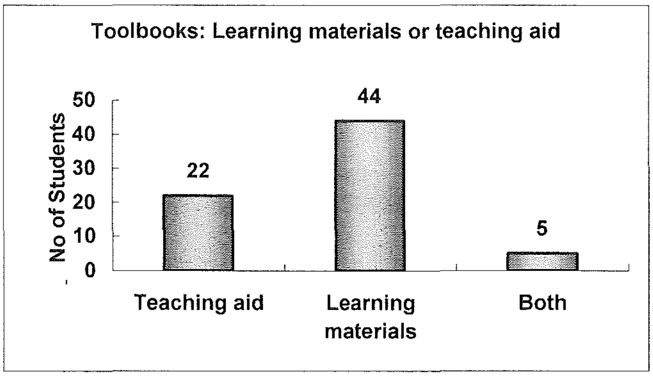


Figure 3-10 Students' perceptions of Toolbooks: teaching aid vs. learning materials

Learning independently with Toolbooks without a tutor (Question 10)

Although 69% (49/71) of the students perceived Toolbooks as learning materials (or either both), only 30% (21/71) considered that they could learn from Toolbooks independently without a tutor.

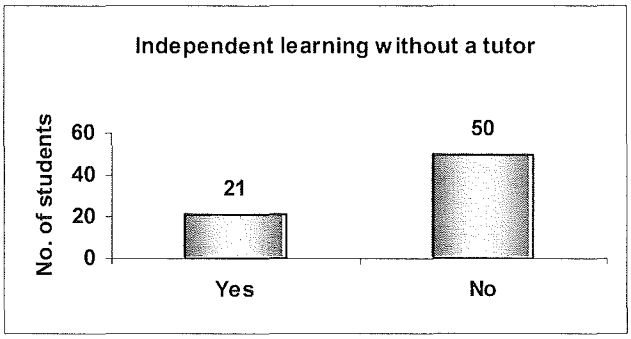


Figure 3-11 Students' responses of learning with Toolbooks without a tutor

As displayed in Figure 3-9 , 89% (63/71) of the students cited that Toolbooks should be both a teaching aid and independent learning materials. Students' responses to these questions raised a question: 'What caused the students to perceive they could not learn with Toolbooks independently without a tutor?' It may be led by students' preferences of having Toolbooks for both teaching and learning; their realisation of the benefits of having them for both; of the poor usability of the materials, which will be described later. Further analysis was carried out to get some answers for these results. How students viewed the usability of Toolbooks was explored for possible associations.

D. Usability of Toolbooks

How easy to find a concept

Students' responses to the question about 'finding a concept in Toolbooks' were displayed in Figure 3-12. Among the students, 26 (37%) considered finding information in the materials difficult. This suggests some usability problems of Toolbooks as learning materials. As described in Appendix 2, the navigation and interface of each Toolbook was simple; therefore, students' responses of finding a concept rather difficult could be led by the navigation between 16 Toolbooks.

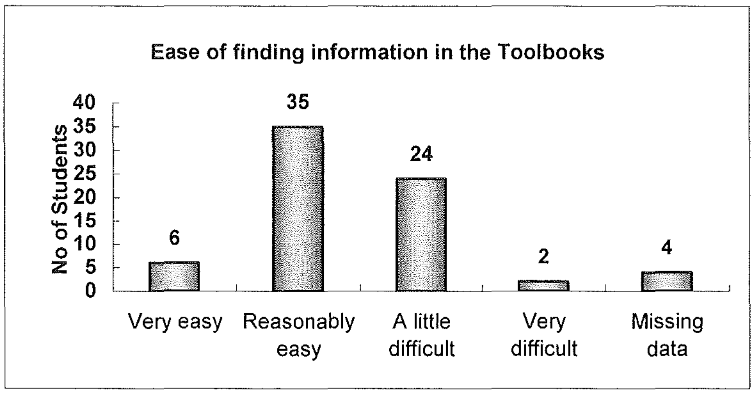


Figure 3-12 Ease of searching in Toolbooks

To determine whether the usability of Toolbooks were related to students' responses to Question 10 (learn with Toolbooks without a tutor), their answers were compared between the two questions. Students' responses are summarised in Table 3-8.

	Learning from Toolbooks without a tutor			
		Yes	No	Total
Easy to find a topic	Very easy	4	2	6
	Reasonably easy	11	24	35
	A little difficult	4	20	24
	Very difficult		2	2
	Total	19	48	67

Table 3-8 Learning from Toolbooks independently vs. easy to find a topic

The students, who responded that they could not learn independently with Toolbooks without a tutor, considered 'finding a topic' difficult more than the others. To determine whether the association between the variables were significant, a Chi-square test was performed. There appeared to be a significant association between the two variables ($\chi^2 = 6.9$; df=3; $p<0.05$). Students' responses to Toolbooks failings (Question 11), features to be added (Question 15) and modified in Toolbooks (Question 16) can enlighten this result more clearly.

Weaknesses of Toolbooks (Question 11)

The weaknesses of Toolbooks that the students were identified and they were: interface;

difficult navigation; insufficient information; illegible text size; and technical problems (difficulties of external use).

Features to be added and modified (Question 15 & 16)

The features that students cited to be added are listed below.

- Index (menu) (32 students)
- Search facilities (25 students)
- Glossary (19 students)
- List of objectives (2 students)
- Detailed explanation/ Examples/Tasks (5 students)
- Hyperlinks : Accessibility to other related topics (2 students)

Not surprisingly, most things students cited were related to usability issues. Many students suggested menu and search facilities to be added. Some wanted to have more information. Students' responses for the features to be modified were similar to ones to be added. In addition to the items the students listed to be added, they suggested a few more things to be modified and they were as follows:

- The interface of Toolbooks (5 students)
- Easy access to the content : index(menu), search and etc. (3 students)
- Graphics / More detailed graphics (2 students)
- Control of Animation
- User input
- To be an independent learning material
- Proper technical support

These results reported here reveal needs for improving the usability of Toolbooks in order to support student independent learning. System usability is fundamental to educational materials. The results reveal how much it can affect student learning; more than 50% students who even used the materials in and out of lectures did not consider they could learn from Toolbooks without a tutor. The reason may not be caused by the poor usability alone; however, it had affected students' perceptions.

3.6. Summary

This study explored teaching and learning with two introductory programming modules at Napier and Brunel universities. The results from the interviews with the module leaders, *Lecturer N* and *Lecturer B*, the questionnaire survey with students, and the assessment of the existing materials yield useful information in three areas. One was identifying difficulties in teaching the subject matter from the lecturer's perspective. The second was identifying useful design features for the subject matter and an effective use in the contexts. The third was identifying areas where IMM courseware should support in order to facilitate student learning. The requirements identified at Napier and Brunel universities were that IMM courseware in the learning contexts should:

- facilitate and encourage independent/active learning;
- support teaching and learning in lectures;
- help students integrate theoretical learning in lectures and practical programming tasks in tutorials;
- support weak students to grasp an understanding of programming concepts.

The third requirement was identified from the interviews and the observations during the pilot study, reported at Brunel University. When students were doing programming tasks in tutorials, two groups of students were observed. The first group, minority, were students who actively engaged their tutors in their programming tasks; they nearly dominated their tutors' time. The other group, the majority, were students who did not do much work. Unfortunately, these students did not seek help from their tutors. They did not seem to know where to start or what to do in order to do the task. This suggests that learning supports which can guide these students to programming are much needed.

The strengths of Toolbooks identified were: 1) its use in the context; 2) visualisation for teaching and learning with programming; and 3) content structure and information representation. Because of its use in lectures, it supported teaching and learning in lectures. This also probably encourages students to use Toolbooks for learning. As for visualisation, this was the main feature which students had perceived beneficial even though some students did not consider Toolbooks had helped their learning. In addition, the content was structured in a simple way and information was presented concisely, which students perceived helpful for their understanding. As discussed in Section 2.4.1, Mayer and Moreno (2002) found that with concise information representation, students performed better.

The weaknesses of Toolbooks identified were: poor usability and lack of interactive tasks which can support student learning. These should be improved by IMM courseware design and use in the context.

CHAPTER 4 A DESIGN & INTEGRATION APPROACH WITH IMM FOR PROGRAMMING

This chapter presents a design and integration approach developed from the literature review on learning, frameworks for learning and IMM (Chapter 2), and the results of the preliminary study, reported in the previous chapter. The primary aim of this approach is to facilitate student learning of programming, and it aims to achieve it through supporting both teaching and learning processes.

Section 4.1 and section 4.2 present the aim and description of the design and integration approach with IMM courseware, this thesis proposes, for teaching and learning of programming domains. Section 4.3 illustrates design features of IMM courseware, and Section 4.4 describes how the design and integration approach supports Fowler and Mayes' learning framework and Laurillard's conversational framework. The last section describes the design and development of IMM courseware.

4.1. Aims of the design and integration approach

Creating learning environments which support interactions between students and a tutor, is essential to facilitate student learning. However, it is not always possible or easy to facilitate the interactions in a situation like having more than 100 students in a lecture theatre. If it is difficult to support interactions between the teacher and the student with conventional teaching methods, what is an alternative way to facilitate the interactions required for learning? One solution can be to use IMM courseware to facilitate student learning through integrating it for both teaching and learning in a way that can help support the interactions.

The theoretical review on learning and IMM, and the preliminary study have yielded valuable information of what IMM courseware should do in order to facilitate student learning. In addition, the preliminary study has produced the requirements for IMM courseware for the learning contexts in which they were to be used (Section 3.6).

This approach is grounded in the view that teaching and learning processes are an 'iterative' process and the learning context in which students learn affects how students experience learning (Section 2.1). Based on this, the design and integration approach aims to contribute in creating a learning context which enhances teaching and learning processes and encourages active learning (Section 2.1 and Section 2.2). As to facilitate learning, the approach aims to support the learning cycle proposed by Fowler and Mayes (1997). It also aims to facilitate the interactions between the teacher, the student and the content specified in Laurillard's conversational framework (2002) (Section 2.3.2). These frameworks are used as a basis to develop this approach, and how this approach supports the two frameworks is described in Section 4.4.

In terms of supporting teaching and learning with the subject matter (the requirements identified from the preliminary study in Section 3.6), it aims:

- to encourage students to approach programming holistically;
- to support teaching and learning abstract concepts;
- to promote independent and active learning;
- to improve weak students' motivation and interests in the subject matter.

The analysis of data from the preliminary study informed the role of Toolbooks and PowerPoint slides in the context, which is illustrated in Figure 4-1.

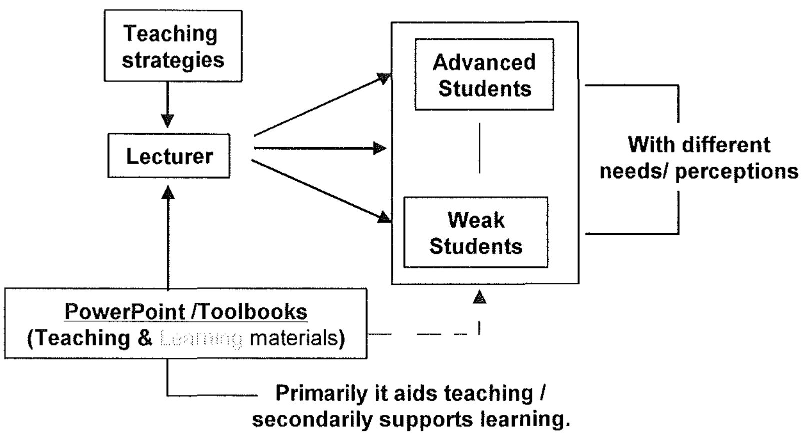


Figure 4-1 Learning and teaching with Toolbooks PowerPoint slides

As illustrated in Figure 4-1, the primary role of both materials was a teaching aid. In order to facilitate student learning effectively, the primary aim of IMM should be to support learning, which is illustrated in Figure 4-2.

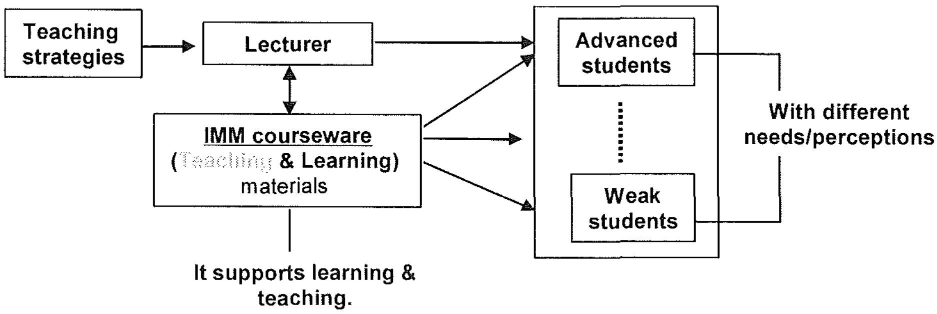


Figure 4-2 Teaching and learning with IMM courseware

As illustrated in Figure 4-2, the design and integration approach aims to enhance student learning experience through supporting both teaching and learning processes. In this context, the primary role of IMM courseware becomes a learning material and the second a teaching aid. In order to achieve this, IMM courseware needs to be fully integrated into the curriculum. Reasons are that:

- both the teacher and the student are subjected to the institutional demands. When IMM is not fully integrated, it can be neglected to use (Laurillard, 2002);
- repeated and continued use of IMM is required for learning: even with well-designed IMM courseware, the student needs to use it repeatedly in order to have better retention and understanding;
- the 'iterative' learning and teaching processes should be supported to improve the quality of student learning;
- IMM courseware needs to be integrated with other learning materials to better facilitate learning.

Other design and integration requirements identified from the literature review and the preliminary study for this approach are as follows:

The architecture of IMM courseware

- It should be appropriate to support teaching and learning activities in the context.
- It needs to support the module structure.
- It should be structured to encourage active learning.

Design of learning activities within and with IMM

- IMM courseware should encourage students to apply their knowledge (what they learnt in lectures) in problem-solving context.
- It should promote the learning process – particularly reflection and 'internal' dialogue.

Interface design

- It should be suitable for both teaching and learning.
- It should help the student to focus on learning the content.
- It should encourage students to use it for independent learning.

Navigation / Content structure

- It should be easy to access information.
- It should help students apprehend the structure of the topic presented.
- It should be easy for a lecturer to use it in lectures.

Information representation

- It should support teaching and learning of the subject matter.
- It should help students understand the meaning of the topic presented.
- It should support students to approach programming holistically.

4.2. Description of the design and integration approach

The integration approach and architecture of IMM courseware in a learning context is illustrated in Figure 4-3.

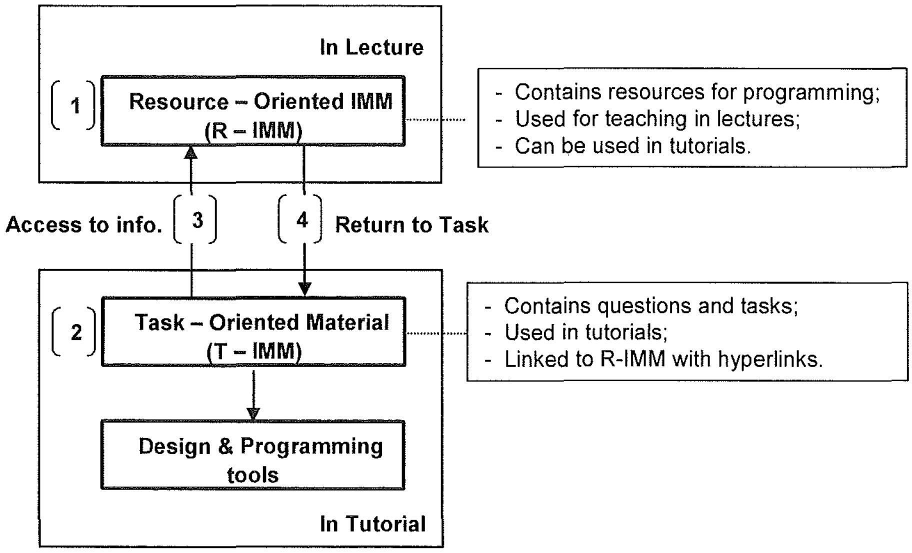


Figure 4-3 The design and integration approach

As illustrated Figure 4-3, this approach proposes to use IMM courseware in both lectures and tutorials. Three main benefits are expected from the use of IMM courseware in the context. One is that this will assist teaching and learning of programming with visual aids in lectures. The second is that in lectures and tutorials it will support the learning process with features, i.e. tasks and feedback, IMM can offer for learning. The third is that it will enhance learning through supporting the 'iterative' learning and teaching process. This is illustrated in Figure 4-4.

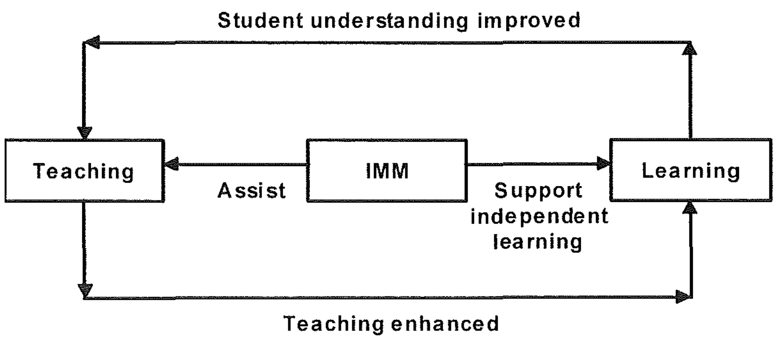


Figure 4-4 The integration approach supporting teaching and learning processes

As illustrated in Figure 4-4, learning is enhanced not only by what IMM courseware can offer but it is also enhanced by teaching practice and repeated use of the courseware. The approach with more detailed description is illustrated in Figure 4-5.

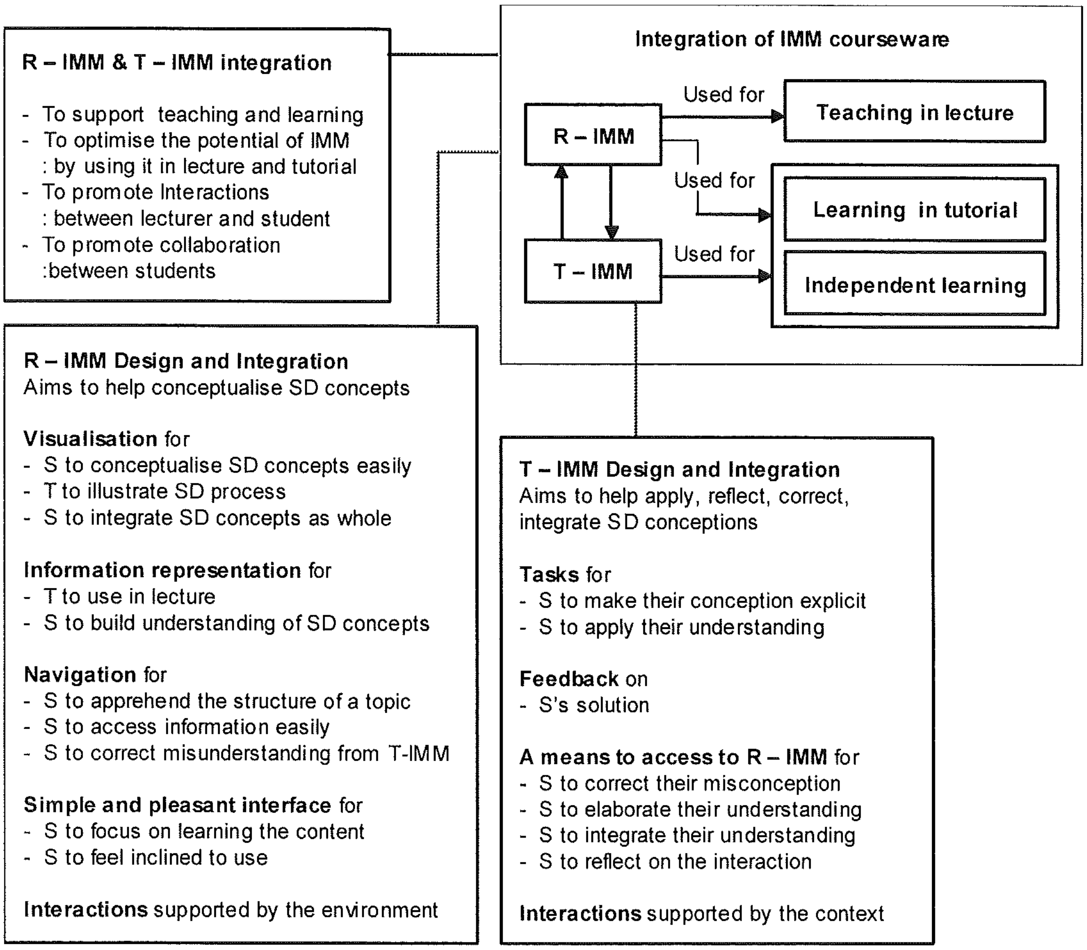


Figure 4-5 Detailed aspects of the design and integration approach (T = Tutor; S = Student)

As illustrated in Figure 4-3 and Figure 4-5, the architecture of IMM courseware consists of two different types of materials: a Resource-oriented IMM material (R-IMM) and a Task-oriented IMM material (T-IMM).

[1] Design and integration of Resource-oriented IMM material (R – IMM)

As its name implies, R-IMM contains resources for programming subject matters which can be tailored to teach programming modules. This is aimed to support teaching in lectures and learning in tutorials or for independent learning. To support teaching and learning, the content design of R-IMM focuses on visualising the abstract programming concepts and on presenting a clear structure of a topic. Having described briefly the role of T-IMM, the design features of IMM courseware will be illustrated.

[2] Design and integration of Task-oriented IMM Material (T – IMM)

Students making conceptions of an idea or theory; thus exposing their misunderstanding, and applying their knowledge in problem-solving tasks are important in learning. Laurillard (1995) asserts that if a multimedia material can provide an environment in which students can reflect on what they already know and relate that to the new information presented to solve a problem, deep understanding can occur. By using T-IMM in tutorials, this integration approach aims to create problem-solving contexts in which students can apply their understanding, in this context what they learnt in lectures.

T-IMM contains questions and tasks with which students can test and apply their understanding. This should be integrated as a part of tutorial materials and used in tutorials. To help students describe, correct and apply their conceptions, different types of tasks should be designed: open questions, multiple-choice question, fill-in questions and design and programming tasks with open questions. The purpose of tasks in T-IMM is to help students correct their misconceptions. Correcting students' misconceptions requires first making students aware of their misconceptions and then to correct them through visiting or revisiting related information. To support this, with tasks T-IMM provides feedback in a form of model answers and hyperlinks with which students can access related information directly in R-IMM. Hyperlinks design in T-IMM is illustrated in Figure 4-6.

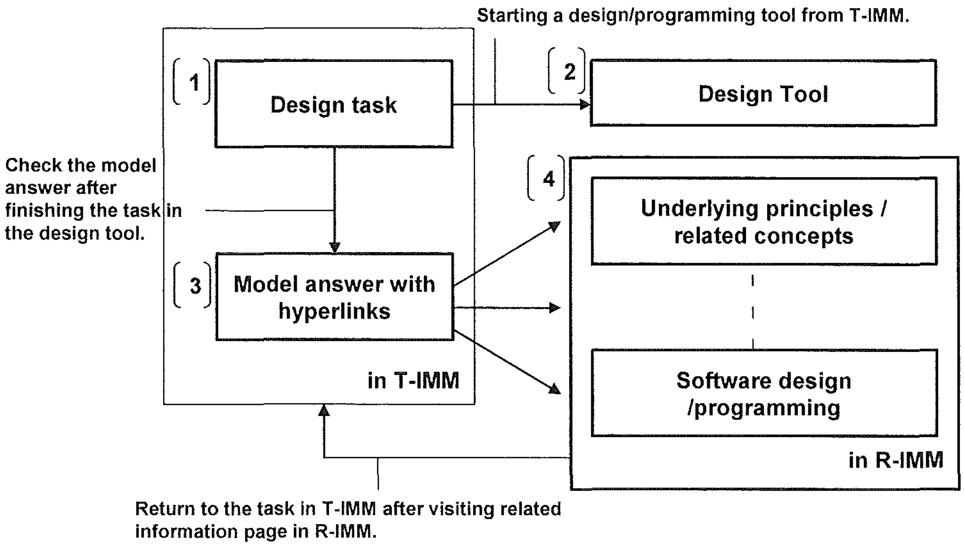


Figure 4-6 Hyperlinks in IMM courseware

One of two main intentions is to help students realise their misconceptions and identify areas where their understanding needs to be improved. As illustrated in Figure 4-6, students can revisit R-IMM with hyperlinks. When they revisit R-IMM, it will help students reflect in what they learnt with R-IMM or a lecturer's explanation during lectures. The second intention is to help students approach programming processes holistically. For example, as displayed in Figure 4-6, with a design task hyperlinks will be provided to access both underlying programming concepts and design process. As for programming tasks, hyperlinks will be provided for underlying concepts, design and programming methods required to understand. This aims to support students to conceptualise, construct and link programming concepts through problem-solving tasks.

[3] Access to related information

As described, hyperlinks are embedded with questions and tasks in T-IMM, with which students can access related information in R-IMM. Two different types are implemented in T-IMM: one displayed with questions, and the other provided with model answers when answered incorrectly. The first is to encourage students to elaborate their answers through visiting related information before answering the question. The intention of the latter is to promote reflection, and to expose and correct students' misconceptions. The effectiveness of the two types of hyperlinks was evaluated in the pilot study (Chapter 5) and case study 1 (Chapter 6).

[4] Return to tasks

After students access information in R-IMM to clarify their understanding, they can continue to use it; or at any time they can return to the task in T-IMM.

Integration with other materials and programming tools

In addition to providing direct access to related information in R-IMM, design or programming tasks in T-IMM provides (should provide) design or programming tools together with tasks. With a link provided in T-IMM, students can start a design tool (case study 1). The process is illustrated in Figure 4-7.

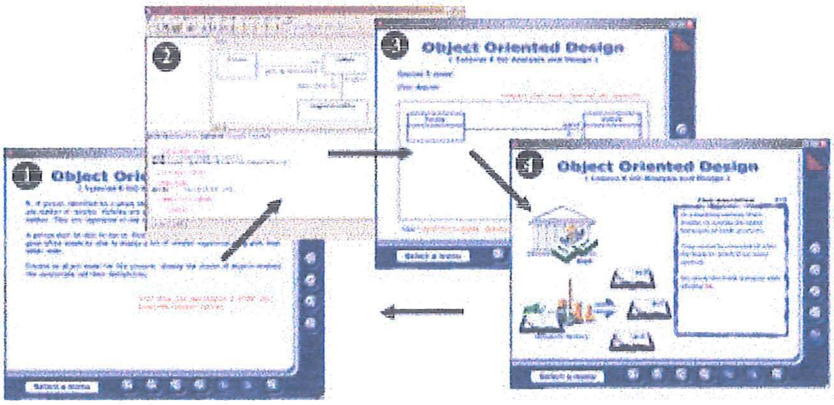


Figure 4-7 Students' use of T-IMM in tutorials (Appendix 15 CD 'IMM OO & IMM C++': 1.Task 5 of Tutorial 5 in T-IMM OO, 2. Design tool 'ROME', 3. Model answer for task 5 of Tutorial 5, 4. Page 6 of Lesson 5 in R-IMM OO)

The screenshot displayed in Figure 4-7 is taken from the IMM courseware developed and used in case study 1 (chapter 6), of which the interface and content design will be described later. When students do design tasks in a design tool, they can use both the tool and T-IMM (even R-IMM) simultaneously. Having finished the design task or programming task, they can check the model answer provided; students are recommended to check the model answer after they try their own solution first. As part of feedback hyperlinks will be displayed, with which students can directly access related programming concepts in R-IMM.

4.3. Design features of IMM courseware

This section describes design features used for IMM courseware, the interface design, content structure, navigation and etc. IMM courseware developed for case studies 1 and 2 are based on what the design and integration approach proposes. To illustrate design features or interface design, sample screenshots from the courseware will be used.

A. Design features: animation design

Two of main design features the design and integration approach proposes are: hyperlinks and animations. Hyperlinks design and its purpose was described in Section 4.2. The approach used for animation design is presented in this section. Two sample animations are illustrated in Figure 4-8 and Figure 4-9. The animation presented in Figure 4-8 is from the IMM courseware (IMM OO) developed for object-oriented design for case study 1, and the animation in Figure 4-9 is from the IMM courseware (IMM C++) for C++ programming.

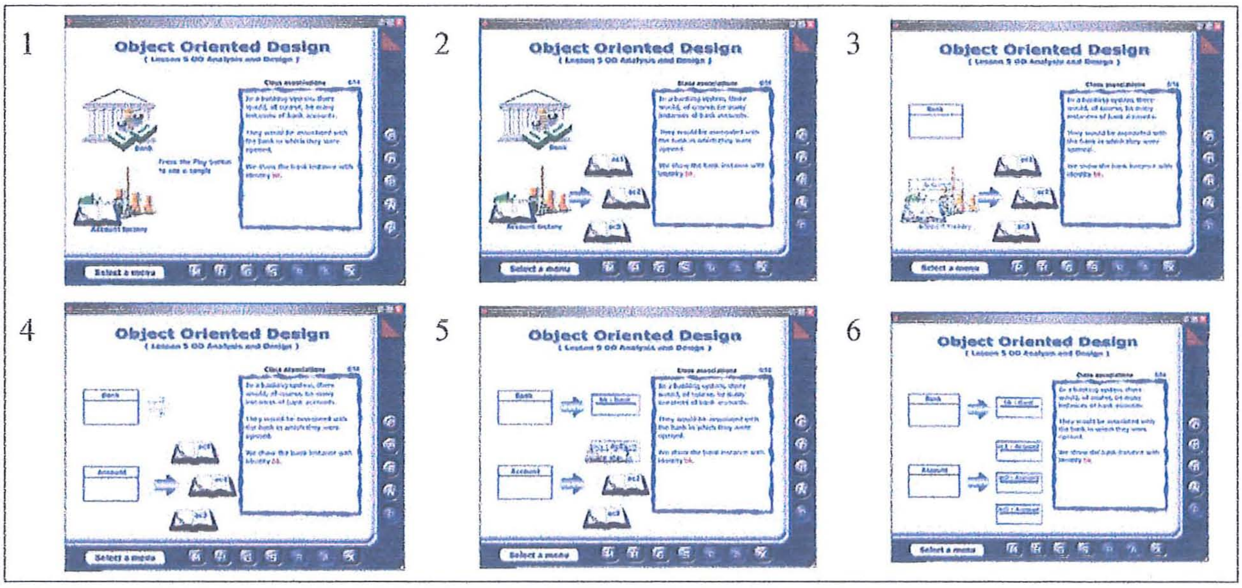


Figure 4-8 The sequence of an example animation: illustrating classes & objects with real life objects (Appendix 15 CD 'IMM OO & IMM C++': Page 5 'Class association' of Lesson 5 'OO analysis and design' in R-IMM OO)

As displayed in Figure 4-8, animations illustrated concepts with real life objects. The purpose is to help students understand the object-oriented concepts and the relationship between analysis and design processes.

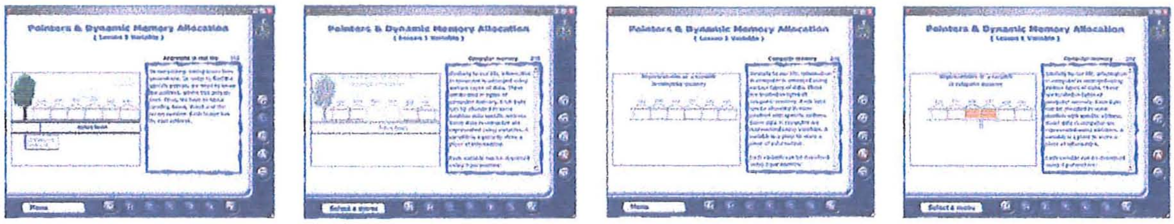


Figure 4-9 Part sequence of an example animation: relating address in real life to computer memory (Appendix 15 CD 'IMM OO & IMM C++': Page 2 'Computer memory' of Lesson 1 'Variable' in R-IMM C++)

As illustrated in Figure 4-9, the same design approach was used for C++ programming as well. As for IMM C++, animations later illustrate the relations between concepts and their implementations in programming. The summary of how visualisation and hyperlinks design in the design and integration approach supports the programming processes is presented in Table 4-1.

Stage	Animation	Hyperlinks
Stage 1: Conceptualising concepts	Visually illustrating abstract concepts with real life objects.	Assisting to: · conceptualise the concepts; · link and integrate the concepts; · clarify the concepts; · correct students' misconception.
Stage 2: Design	· Illustrating software design process · Visualising the concepts in software design.	Assisting to: · apply the concepts in software design; · correct students' misconceptions; · re-conceptualise the concepts in software design processes.
Stage 3: Implementation	· Illustrating the concepts in a programme. · Bridging the software design and implementation.	Assisting to: · apply the concepts in software development processes; · correct students' misconceptions; · re-conceptualise the abstract concepts in software development processes; · help students solve programming tasks through providing a means to underlying concepts and software design processes.

Table 4-1 Visualisation & hyperlinks design for students' understanding of programming processes

As described in Table 4-1, hyperlinks design in T – IMM aims to support the learning process through promoting cognitive interactivity – reflection and cognitive dialogue. The aim of animation design is to visualise programming concepts and to relate the concepts to design and programming processes.

To help students link programming concepts, the real life objects used for animations are (should be) used continuously. Examples of two animations from IMM C++ are illustrated in Figure 4-10.

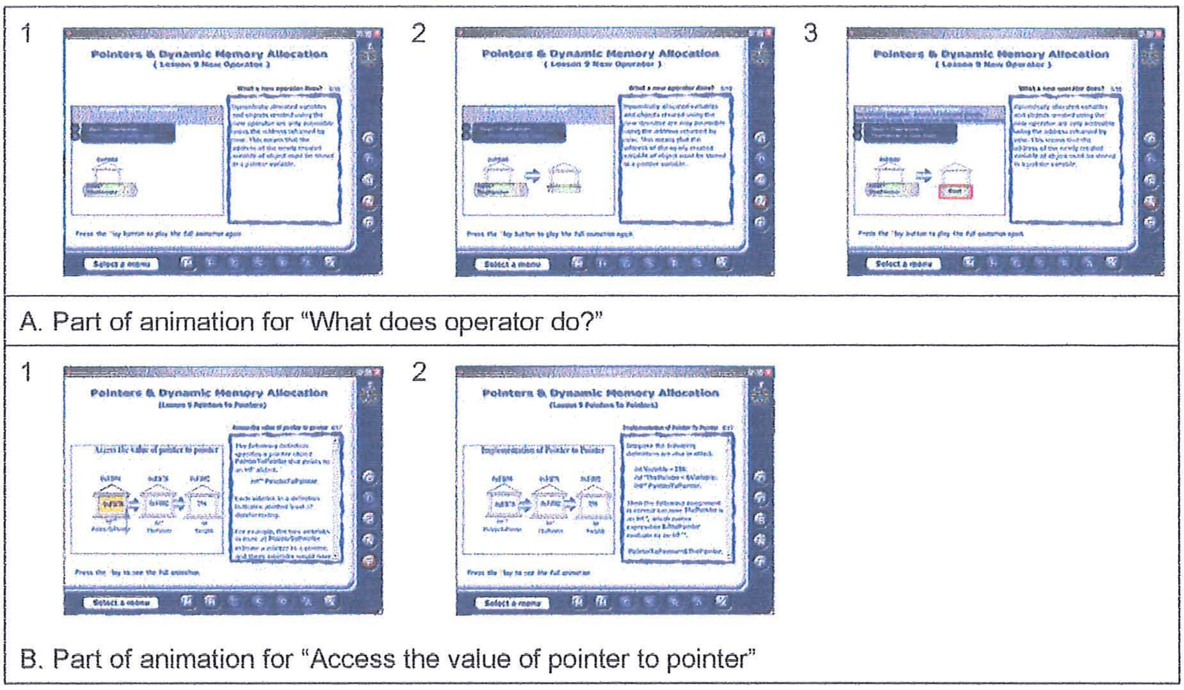


Figure 4-10 Examples of continuous use of the same real life objects for animations (Appendix 15 CD 'IMM OO & IMM C++': A. Page 5 'What does a new operator do?' of Lesson 9, B. Page 4 'Access the value of pointer to pointer' of Lesson 5 'Pointer to pointer' In R-IMM C++)

As displayed in Figure 4-10, the same real life objects are used for C++ programming concepts.

B. Interface and content design

System usability is an important issue in designing IMM courseware. The results from the preliminary study (chapter 3) also revealed that poor usability and interface can discourage students' use of learning materials even if they are integrated and used for teaching. The interface and navigation of multimedia courseware needs to be designed to provide good usability and pleasing looks as well as supporting the learning process. Well-chosen colour schemes, coherent information representation with appropriate media selection and clear layout could help students focus on their learning without getting displeased or distracted by its appearance or poor usability.

Content design in this study is approached to find effective ways to engage students in learning and to motivate them to use IMM for their independent learning. At the same time the content design is suitable for teaching.

Interface design and navigation

A sample screenshot of the interface is displayed in Figure 4-11. As IMM courseware should be used for both teaching and learning, the aim of the interface design lies in its simplicity.

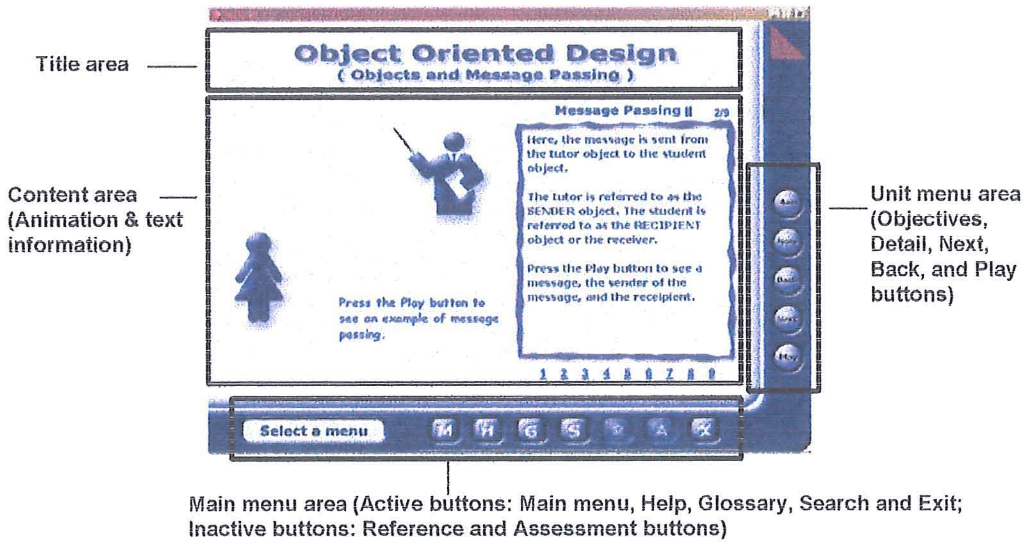


Figure 4-11 Interface of IMM (Appendix 15 CD 'IMM OO & IMM C++': Page 2 'Message passing II' of Lesson 2 'Object and Message passing' in R-IMM OO)

The interface design and navigation of IMM provide:

- simple and consistent interface that support students to focus on learning the content, rather than operating the material;
- friendly and pleasing interface to encourage students to use IMM for independent learning.

As displayed in Figure 4-11, the interface is divided into four areas which are:

- title area;
- content area – visual and textual information with a topic title;
- unit menu area providing navigation buttons for a unit;

- main menu area providing navigation buttons for the main menu, support facilities, exit and etc.

Navigation is designed for easy access to the information required. R – IMM provides a random access to a topic in a main menu. Also, students can access support facilities such as help, search and menu at any time. However, they can navigate linearly in a lesson or a tutorial unit.

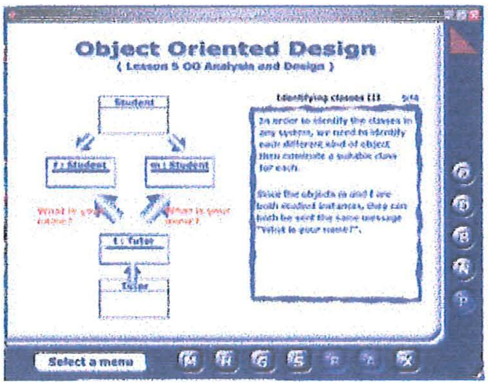
Content structure

The content of IMM courseware is structured to help students grasp overall structure of programming principles (construct understanding systematically). It also aims to help teaching in lectures. The content of IMM courseware is divided into several units and each unit into several related topics to present a clear structure of each concept and their interrelationships in programming process. A sample screenshot of the content structure of IMM is presented in Figure 4-12.

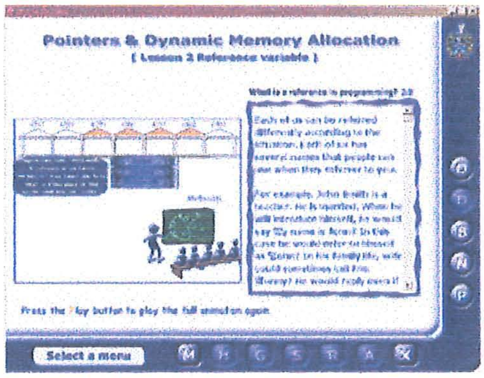
Figure 4-12 The content structure of IMM (Appendix 15 CD 'IMM OO & IMM C++': 'Main menu' in R-IMM OO)

Information representation

In R–IMM, information is represented with text and visualisation. As described above, animation is designed to visualise abstract programming concepts and how they are related and applied in software design and development phases. To promote interactions between students and IMM courseware, the text information is written in a narrative tone with an easy description. The narrative tone is also used for instructions so that students can feel at ease when they use the IMM OO for independent learning. The information representation in IMM OO and IMM C++ is illustrated in Figure 4-13.



A. content page in IMM OO



B. content page in IMM C++

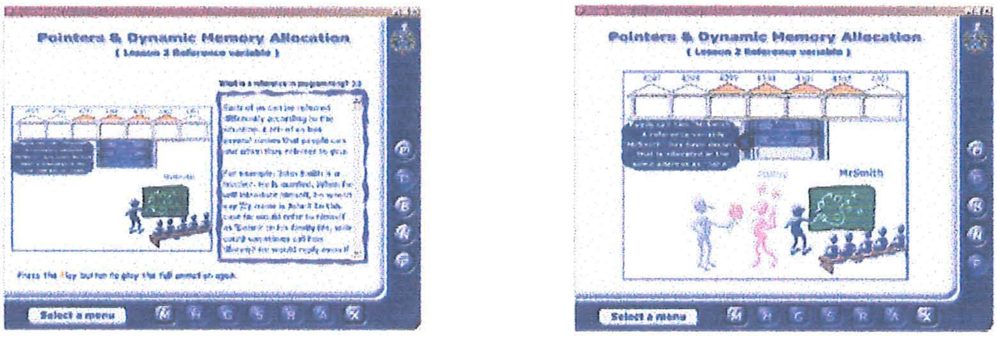
Figure 4-13 Information representation with animation and text information (Appendix 15 CD 'IMM OO & IMM C++': A. Page 5 'Identifying classes III' of Lesson 5 'OO analysis and design', B. Page 2 'What is a reference in programming?' of Lesson 2 'Reference variable' in R-IMM C++)

As displayed Figure 4-13, animations are placed in the left side of the content area. Students can play animations with the play button in the unit menu area. This is the main design approach this design and integration approach proposes. The reason is presenting two media together for a message can enhance students' understanding (Mayer & Moreno, 2002) although there are some contradictory evidences (Vetere & Howard, 1999). However, because of the complexity of animations and the screen size, different approaches are used for IMM OO and IMM C++. Sample screenshots of the content pages when animation is played in IMM OO and IMM C++ are displayed in Figure 4-14 and Figure 4-15.

A. content page B. animation played

Figure 4-14 Information representation with animation and text information in IMM OO (Appendix 15 CD 'IMM OO & IMM C++': Page 2 'Message passing II' of Lesson 1 'Object and message passing' in R-IMM OO)

As displayed in Figure 4-14, animation is played on the same page.



A. content page B. animation played

Figure 4-15 Examples of content page and animation played in IMM C++ (Appendix 15 CD 'IMM OO & IMM C++': Page 2 'What is a reference in programming?' of Lesson 2 'Reference variable' in R-IMM C++)

As for IMM C++, animation is played on a separate page. When the animation is finished, by clicking either a key or mouse, the user can go back to the content page.

Information layering for teaching and learning

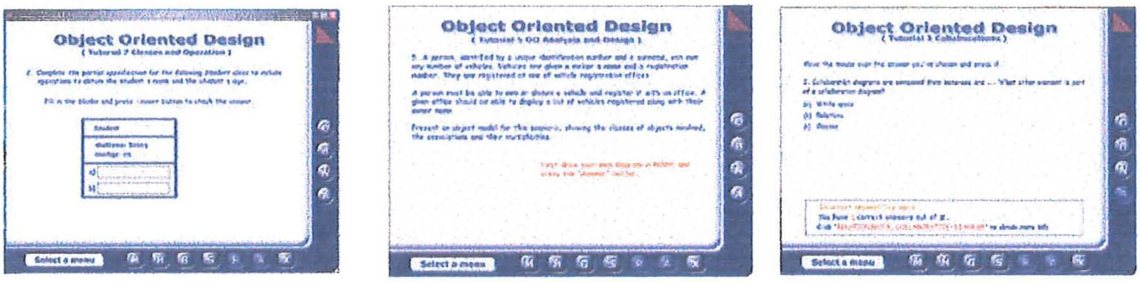
In addition, the text information for each topic is layered to accomplish two objectives. The first is to help students grasp the structure of a topic with a concise and simple description as the lecturer intends and build their understanding with the proper structure. The latter is to support teaching.

- one layer providing brief text information to assist teaching and initial learning;
- the other layer providing more detailed information on each topic to support

independent learning. The detailed information can be accessed by a button on the unit button area.

Questions and tasks in T-IMM

In T-IMM, questions and tasks are (should be) designed in different styles suitable for the topics. Examples of questions and design tasks in T-IMM OO are displayed in Figure 4-16.



A. Fill-in question B. Design task C. Multiple choice question

Figure 4-16 Examples: fill-in questions, design tasks and multiple choice questions with hyperlinks (Appendix 15 CD 'IMM OO & IMM C++': A. Question 2 of Tutorial 7, B. Task 5 of Tutorial 5, C. Question 2 of Tutorial 3 in T-IMM OO)

Additional features: help, search and glossary

To support students' learning, help, search and glossary features should be added. A sample screenshot of the 'glossary' feature in IMM OO is illustrated in Figure 4-17.

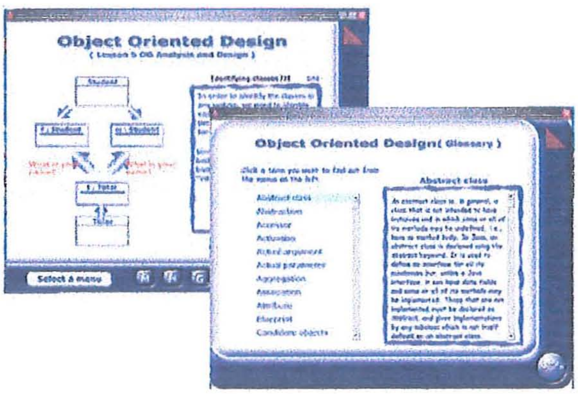


Figure 4-17 Glossary in a separate window from IMM (Appendix 15 CD 'IMM OO & IMM C++': 'Glossary', accessed from R-IMM OO)

As they are support facilities, they should be opened in a separate window so that students can use both at the same time.

4.4. The design and integration approach supporting the learning process

Fowler and Mayes' learning framework and Laurillard's Conversational Framework (CF) are part of the theoretical groundings of the design and integration approach. As discussed in Section 2.3.1, Fowler and Mayes' learning framework illustrates the learning process with three phases. In addition, they describe the types of educational materials that can support the three phases. The CF, discussed in Section 2.3.2, specifies the interactions to be supported between the lecturer (or IMM courseware) and students in teaching and learning processes. How the design and integration approach and courseware design supports Fowler and Mayes' learning framework and the CF will be described in this section.

4.4.1. Supporting Fowler and Mayes' learning framework

How the design and integration approach supports the learning framework is illustrated in Figure 4-18.

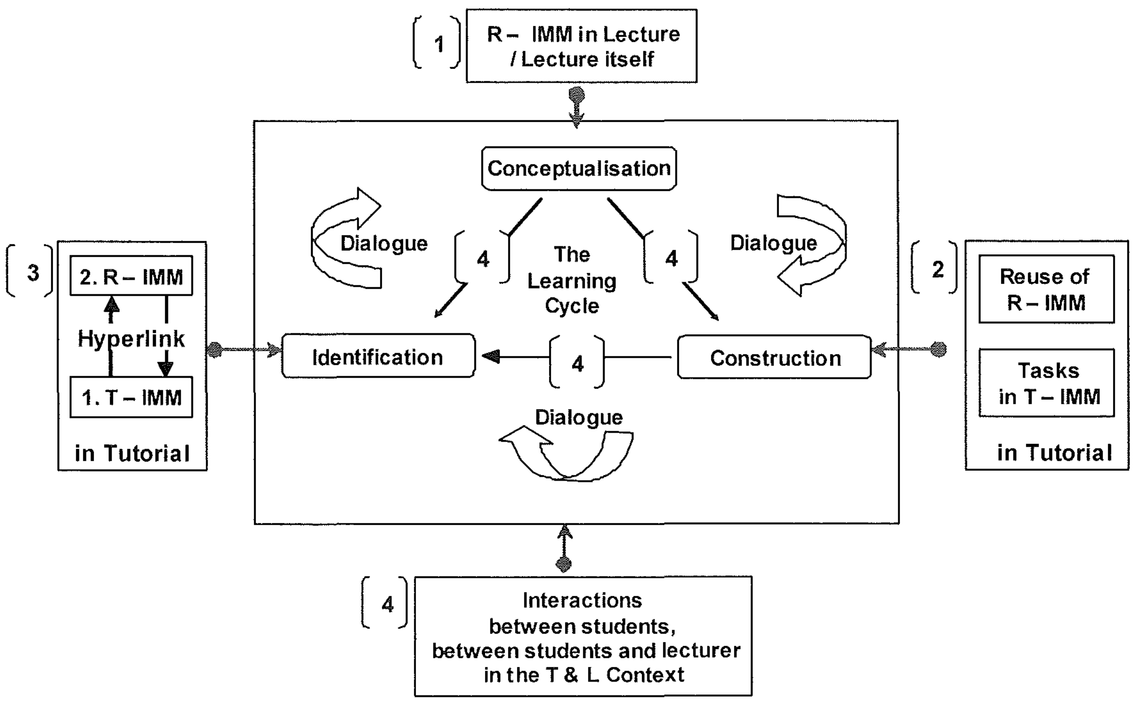


Figure 4-18 The design and integration approach supporting Mayes' learning framework

[1] Supporting conceptualisation phase

Teaching with R-IMM in lectures and learning with it in tutorials or independently support three conceptualisation phase. Students can conceptualise programming concepts through contacting R-IMM in lectures, and later learning with it in tutorials or independently. The content in R-IMM is structured for students to apprehend the structure of the topic presented as the lecturer intended, and information is layered to help students build their knowledge in a systematic way. Objectives and a summary of each topic and the overall structure of R-IMM are presented to help students understand programming holistically. In addition, visualisation helps students conceptualise abstract programming concepts and link them to their experiences.

[2] Supporting construction phase

Students reusing R-IMM after lectures can reinforce the conceptualisation phase of the learning process. Students use T-IMM in tutorial which presents tasks. The tasks in T-IMM are linked to the content in R-IMM presented in lecture, which presents students with clear goals. The tasks aim to expose students' conceptions or misconceptions. Students can construct their understanding through applying their knowledge in problem-solving tasks. Based on the feedback students can correct their misconceptions.

[3] Identification phase

Either before answering a question or after answering a question incorrectly in T-IMM, students can access the related information in R-IMM. The first will help students elaborate their answers or solutions for questions or tasks. The latter will help students correct their misunderstanding and promote them to reflect in the lecturer's descriptions of the topic in lectures. Furthermore, as the IMM courseware is used in tutorials, students can interact with their peers and their tutors for discussion.

[4] Supporting dialogue

As both R-IMM and T-IMM are embedded in a classroom environment, interactions between the lecturer and students can be encouraged and supported. In tutorials, T-IMM provides model answers on students' answers and solutions to questions and tasks, and it also provides a means to correct students' misconceptions by visiting related information in R-IMM. Students can compare their solutions and engage in discussion to clarify their ideas. This will support more active interactions between a tutor and students as the tutor can have more time to support students. In the following lecture, teaching will continue to teach with R-IMM, and students can conceptualise the new concept in the lecture integrating it to their existing knowledge.

4.4.2. Supporting Laurillard's conversational framework

In the CF (Figure 2-4), Laurillard (2002) identifies 12 interactions between the teacher and students, which must be supported in order to facilitate learning. She also identifies 5 learning activities required for the learning process. How the design and integration approach supports the CF is summarised in Table 4-2, and the learning activities in Table 4-3 .

	Activities		The design and integration approach
1	T can describe conception	→	▪ T describes conception with R-IMM in lectures ▪ S uses the R – IMM in tutorials or independently
2	S can describe conception	→	▪ S answers questions or does tasks in T – IMM (describing their conception)
3	T can re-describe in light of S's conception or action	→	▪ IMM provides feedback on S's solution on tasks in T – IMM and a means to access the concept in R – IMM
4	S can re-describe in light of T's re-description or T's action	→	▪ S corrects their misconceptions by acting on the feedback from T- IMM: access related information in R–IMM with hyperlinks provided as part of feedback ▪ S interacts with T to clarify their understanding. Acting on the feedback
5	T can adapt task goal in light of S's description or action	→	▪ T adapt task goal in light of S's responses with IMM ▪ Interactive tasks with feedback in T-IMM
6	T can set task goal	→	▪ Objectives and summary in IMM ▪ Feedback on tasks available
7	S can act to achieve task goal	→	▪ S can act to achieve task goal specified by T in tutorials ▪ S can act based on objectives in IMM
8	T can set up world to give intrinsic feedback on actions	→	▪ T–IMM provide feedback on S's answers and a means to access relevant information in R–IMM ▪ Feedback through interacting with IMM, the tutor or peer students
9	S can modify action in light of feedback on action	→	▪ S can use the hyperlink in T-IMM to access related information in R–IMM ▪ S can continue to answer questions or do tasks in T-IMM
10	S can adapt actions in light of T's description or S's redescription	→	▪ When S visit R-IMM from tasks in T-IMM, S can either continue to use R–IMM if needed further understanding of concepts or return to T–IMM
11	S can reflect on interaction to modify redescription	→	▪ S articulate or correct their conceptions through hyperlink ▪ S reflect on discussion with other students or tutor ▪ S reflect on T's descriptions with R-IMM in lectures
12	T can reflect on S's action to modify redescription	→	▪ T help S in tutorial ▪ T reflect on S's interactions with IMM to improve teaching with it in lecture ▪ T–IMM provides feedback on S's answers and hyperlinks for S to articulate their own solutions.

Table 4-2 Descriptions of how the proposed integration approach with IMM courseware design supports interactions in Laurillard's CF (S: students, T: the teacher)

How the design and integration approach supports the five learning activities of the learning process is summarised in Table 4-3 .

Five learning activities	Design and integration approach
Apprehending structure	Clear content structure and navigation Objectives and summary Layered information representation to clearly outline structure Menu depicting the relationships between topics
Interpreting forms of representation	Combination of visualisation and text for information representation Visualisation illustrating programming concepts and processes using real life objects.
Acting on descriptions	Tasks and questions in T–IMM Feedback provided by T-IMM based on students' answers
Using feedback	Feedback on students' answers to the tasks in T-IMM Access to related information in R-IMM to correct misconceptions or elaborate answers for the tasks in T-IMM
Reflecting on goal-action-feedback cycle	Use of IMM for teaching and learning promotes reflection Reflection is promoted in the process that students try to solve tasks in T-IMM, get feedback and acts on the feedback: such as visiting R-IMM to correct their misconceptions; to elaborate their answers; integrate their conceptions, or continue to answer questions.

Table 4-3 The design and integration approach supporting the learning activities

The design and integration approach, proposed in this thesis, suggests IMM courseware to be integrated into the curriculum for both teaching and learning. Therefore, the approach does not try to support the interactions in the CF and the five leaning activities by IMM courseware design alone. It rather aims to facilitate them in the learning context through supporting both teaching and learning processes. What IMM courseware cannot support can be facilitated by its use in the learning context in which students are engaged in learning with the courseware, their tutors and peer students.

4.5. IMM courseware design and development for empirical study

To evaluate the design and integration approach, two IMM courseware were designed and developed. Both were developed as part of course materials for real programming modules at Napier and Brunel universities. As for Napier University, IMM courseware was developed for object-oriented design, and for Brunel University IMM courseware was developed for C++ programming. The architecture and design features of the courseware are already used in describing the design and integration approach. Therefore, this section will present the design and development processes of the courseware. In addition, the content each IMM courseware contains will be described.

4.5.1. IMM courseware design

This study aimed to develop a design and integration approach which can support both teaching and learning. Additionally, with the approach it aimed to help lecturers with limited technical knowledge as well as designers could employ it to design and develop their own teaching materials. To achieve this, the following were considered important and they were as follows:

- clear and simple, but effective design in supporting teaching and learning;
- flexible and easy development and modification;
- cost effective and not time consuming design and development;
- feasible media.

IMM courseware design and development processes

The approach taken for IMM OO and IMM C++ design are illustrated in Figure 4-19. The steps taken the processes are: defining learning objectives; identifying learning needs; designing learning activities; designing the content; developing a prototype; and evaluating it.

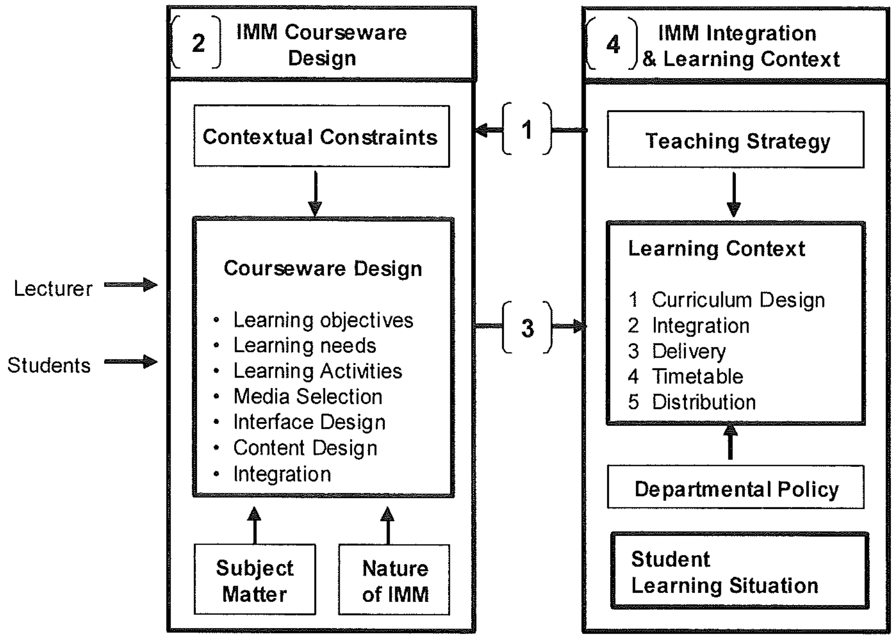


Figure 4-19 The approach taken for IMM courseware design and integration

[1] Investigating the learning context and the subject matter

A preliminary study, investigating teaching and learning of programming modules at two universities (see Chapter 3), was conducted to identify the requirements for IMM courseware design and integration suitable for the subject matters and the learning contexts.

[2] IMM courseware design

IMM courseware, IMM OO and IMM C++, were designed and developed to meet the requirements identified from the universities. The courseware were grounded in the design and integration approach presented in this chapter. However, compromises were made between the lecturers at Napier and Brunel universities and the author in terms of some of features or content design.

[3] Integration & evaluation

As an initial evaluation, a prototype (IMM OO) was developed and its usability was assessed informally at Napier University. Next, its usability and learning effects were evaluated at Brunel University during two three hours tutorials. Based on the results, IMM OO and IMM C++ were further developed, and in the empirical study the effectiveness of the design and integration approach was investigated through evaluating teaching and learning of programming with them. The next 4 chapters will present the description and results of the empirical study: a pilot study and three case studies.

4.5.2. IMM courseware development: IMM OO and IMM C++

Description of IMM OO

IMM OO consists of a Resource-oriented material (R–IMM OO) and a Task-oriented material (T–IMM OO). Three different variations of T – IMM OO were developed to investigate the learning effects of different types of hyperlinks in problem-solving contexts. The three treatment variations are:

- No-hyperlink version: in this version T-IMM provides questions and tasks, but it will not provide hyperlinks either with questions or with model answers;
- Static-hyperlink version: hyperlinks will be displayed together with questions and tasks. Students can directly access related information to the question or the task in R-IMM OO. The hyperlinks embedded aim to encourage students to elaborate their own answers before answering questions.
- Dynamic-hyperlink version: hyperlinks will be provided either after students answer questions incorrectly or after they do design tasks and open questions.

Development of IMM OO & IMM C++

The design and integration approach described in this chapter was applied in developing IMM courseware for IMM OO & IMM C++, which were used at Napier and Brunel universities as part of course materials. As suggested in Section 4.2, students can benefit more if IMM is used for a longer period of time as the following takes time.

- changing their perceptions of learning;
- realising benefits of multimedia for learning;
- getting used to a new learning method and so on.

Both courseware were developed by the author in collaboration with the lecturers at Napier and Brunel Universities. Once agreement was made in terms of the architecture and design features of IMM courseware and its use in the context, work was divided between the lecturers and the author. As for the development of IMM OO, the lecturer at Napier University wrote the text information, glossary, questions and tasks. He also provided ideas for most animations. Hyperlinks were implemented by the author after a careful examining of the content in R-IMM OO, and tasks and questions in T-IMM OO.

As for IMM C++ development, the template created for IMM OO was used for IMM C++. As described in Section 4.3, one difference was information display when animation was played. Initially, the lecturer (*Lecturer B*) at Brunel University provided text content in a word file and ideas for animations. However, *Lecturer N* preferred to implement animations by herself. Graphics required for animations were produced by the author and *Lecturer B* created Flash animations. Later, *Lecturer B* used the template Director file to create each unit of IMM courseware by herself. After checking the units of IMM materials produced by *Lecturer B*, the last packaging was done by the author. As for hyperlinks, they were implemented by *Lecturer B.* The contents of IMM OO and IMM C++ are included in Appendix 3, and more detailed information can be found from IMM OO and IMM C++ themselves in the CD included.

Evaluation

As mentioned above, an empirical study was designed to evaluate the effectiveness the integration approach through investigating teaching and learning with IMM OO and IMM C++.

CHAPTER 5 EMPIRICAL STUDY DESIGN & A PILOT STUDY ASSESSING INDEPENDENT LEARNING SUPPORT

The previous chapter presented a design and integration approach developed from the theoretical review on learning, the learning process and IMM, and the preliminary study in teaching and learning of programming (Chapter 3). To evaluate how effectively this approach facilitates student learning with programming, an empirical study was designed to be conducted in real teaching and learning environments. For the empirical study, IMM courseware, described in Section 4.5, were developed as part of course materials for two programming modules at Brunel and Napier universities.

This chapter presents an overview of the empirical design and a pilot study conducted to evaluate the usability and learning effects of a prototype of IMM courseware for object-oriented design. Section 5.1 presents an overview of the empirical study, and Section 5.2 describes the research methods and data analysis. Section 5.3 reports the pilot study results.

5.1. Overview of the empirical study

This empirical study was designed to investigate whether and how effectively the design and integration approach, presented in the previous chapter, facilitated student learning of programming. The empirical study is summarised in Table 5-1.

As described in Table 5-1, this study consists of a usability assessment of IMM courseware (a prototype), a pilot study and 3 case studies. These were conducted from semester 1 of 2000/2001 academic year until semester 1 of 2001/2002. Two IMM courseware (IMM OO and IMM C++), described in Section 4.5, were developed by the author in collaboration with the module leaders for two programming modules at Napier and Brunel universities. They were integrated into the curriculum of the modules and used in lectures and tutorials.

<table>
<tr><th></th><th>Pilot Study</th><th>Case Study 1</th><th>Case Study 2</th><th>Case Study 3</th></tr>
<tr><td rowspan="2">Aims</td><td rowspan="2">To evaluate:
• Usability
• Learning effects (Content acquisition)</td><td colspan="3">To evaluate:
• Effectiveness of the integration approach in facilitating both teaching and learning in real educational environments;
• Learning effects of the design features for the subject matter chosen;
To explore:
• Factors that affect teaching and learning with IMM courseware.</td></tr>
<tr><td>To compare:
• Learning effects of static and dynamic hyperlinks</td><td colspan="2">To further investigate:
• Cognitive effects of dynamic hyperlinks and visualisation
• Benefits of the integration approach for learning and teaching from the lecturer' perspective</td></tr>
<tr><td>Subject Matter</td><td>Object-Oriented Programming (OOP)</td><td>Object-Oriented Software Development</td><td>C++ Programming</td><td>Object-Oriented Design and Programming</td></tr>
<tr><td>Courseware</td><td>IMM OO</td><td>IMM OO</td><td>IMM C++</td><td>IMM OO</td></tr>
<tr><td>Hyperlinks Design</td><td>No and dynamic hyperlink versions</td><td>No, static and dynamic hyperlink versions</td><td colspan="2">Dynamic version only</td></tr>
<tr><td>IMM Integration</td><td>Integrated into a tutorial</td><td colspan="3">Integrated into lectures and tutorials</td></tr>
<tr><td>IMM Use</td><td>In tutorials</td><td colspan="3">In lectures and tutorials (Teaching/Learning)</td></tr>
<tr><td>Content designer</td><td>Lecturer N</td><td>Lecturer N</td><td>Lecturer B</td><td>Lecturer N</td></tr>
<tr><td>Users</td><td>Students in OOP module</td><td>Students in OOSD module</td><td>Students in P&SD 2 module</td><td>Students in OOSD module</td></tr>
<tr><td>Location</td><td>Brunel University</td><td>Napier University</td><td>Brunel University</td><td>Brunel University</td></tr>
<tr><td>Semester</td><td>Semester 1 of 2000/1</td><td>Semester 2 of 2000/1</td><td>Semester 2 of 2000/1</td><td>Semester 1 of 2001/2</td></tr>
<tr><td>Duration</td><td>Week 10</td><td>Week 1 - 6</td><td>Week 5-End semester</td><td>Week 1 - 7</td></tr>
</table>

Table 5-1 Overview of empirical study

Usability assessment

As a part of the development process, usability assessment of IMM courseware was performed by the author's director of studies (HCI researcher) and an HCI research student, the two module leaders and a lecturer (domain experts and users) in computing at Napier and Brunel universities, and one postgraduate student (a student user) from the Software Engineering course. A prototype of IMM OO, described in Section 4.5.2, was developed, and it contained two lessons in R-IMM OO and two tutorials in T-IMM OO. T-IMM OO was developed in two different variations: one containing questions and tasks with no links to R-IMM OO (no-hyperlink version) and the other with tasks providing links, only when students answered questions incorrectly, to related information in R-IMM OO. Feedback from the assessment was overall positive, and only minor modifications were required to be made in the areas of the interface design. The architecture of the courseware, the simplicity of content structure and information representation were considered suitable for the subject matter and for the context of use. However, there was a concern voiced in terms of the amount of information R-IMM OO contained, which could be insufficient to support independent learning by itself.

An interesting suggestion was made from the HCI research student. When she used T-IMM answering questions, she felt that having direct access to related information in R-IMM before answering them would be more helpful, because she preferred to articulate her own answer finding relevant information than to correct after making incorrect answers. This idea was incorporated in the full development of IMM OO. T-IMM OO was developed with three different versions: the first T-IMM version containing no links to R-IMM OO, the second version presenting links with questions and tasks and the third providing links after either answering questions incorrectly or open questions and design tasks. The learning effects of the three were compared in case study 1. The aims and results of the pilot study and three case studies are illustrated in Figure 5-1 and Figure 5-2. The summary and main findings of the studies are included in Appendix 13.

Pilot study

As illustrated in Figure 5-1, the pilot study aimed to evaluate the usability and learning effects of the prototype of IMM OO. In addition, it aimed to explore the two variations of T-IMM OO. As summarised in Table 5-1, this study was conducted at Brunel

University during two 3 hour tutorials. The summary of main results is presented in Figure 5-2. This study is reported in Section 5.3.

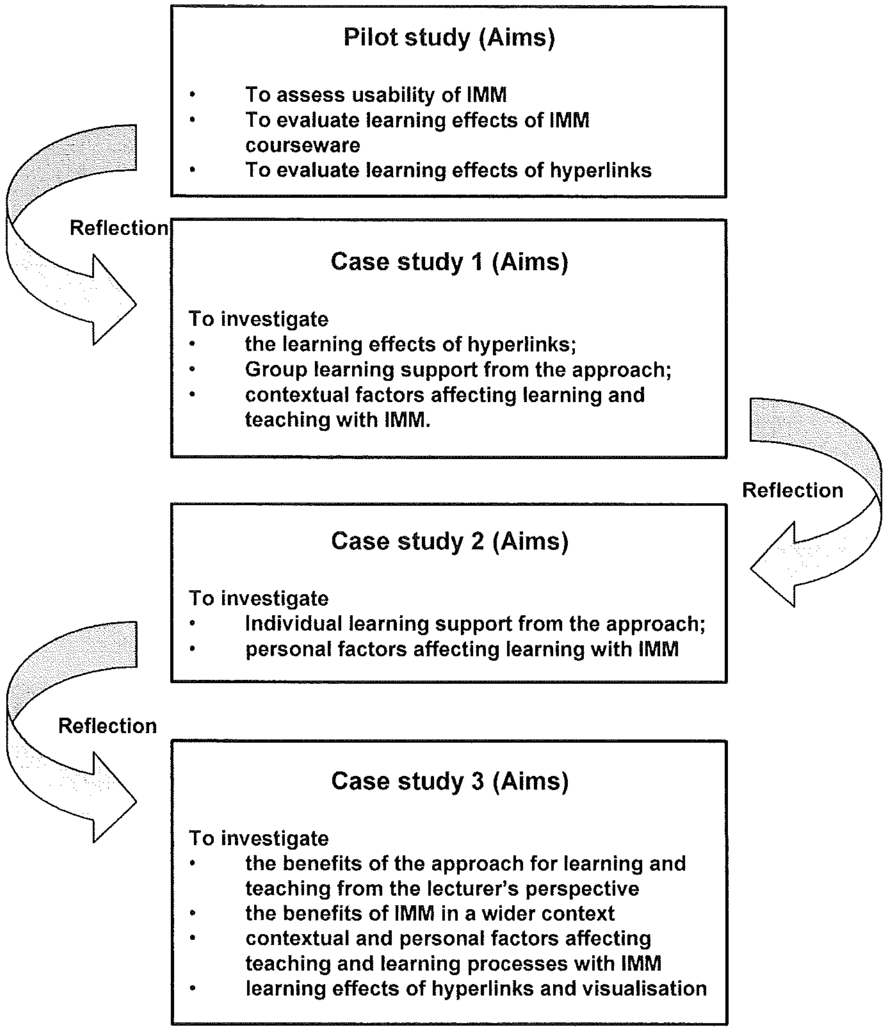


Figure 5-1 Aims of the studies

Case study 1

This study was conducted at Napier University from week 1 until week 6 of semester 2 of 2000/2001. IMM OO was used in both lectures and tutorials. This study aimed to investigate the learning support of the approach and to evaluate the learning effects of hyperlinks with three different variations of T-IMM OO (Section 4.5.2). In addition, it aimed to explore contextual factors affecting learning and teaching with IMM. The main results from the study is summarised in Figure 5-2. The results of two tests performed in week 4 and week 6 revealed that the dynamic-hyperlink user group performed significantly better than the other two groups. Based on this result, in case studies 2 and

3, only the dynamic-hyperlink version of T-IMM was used. This study is reported in Chapter 6.

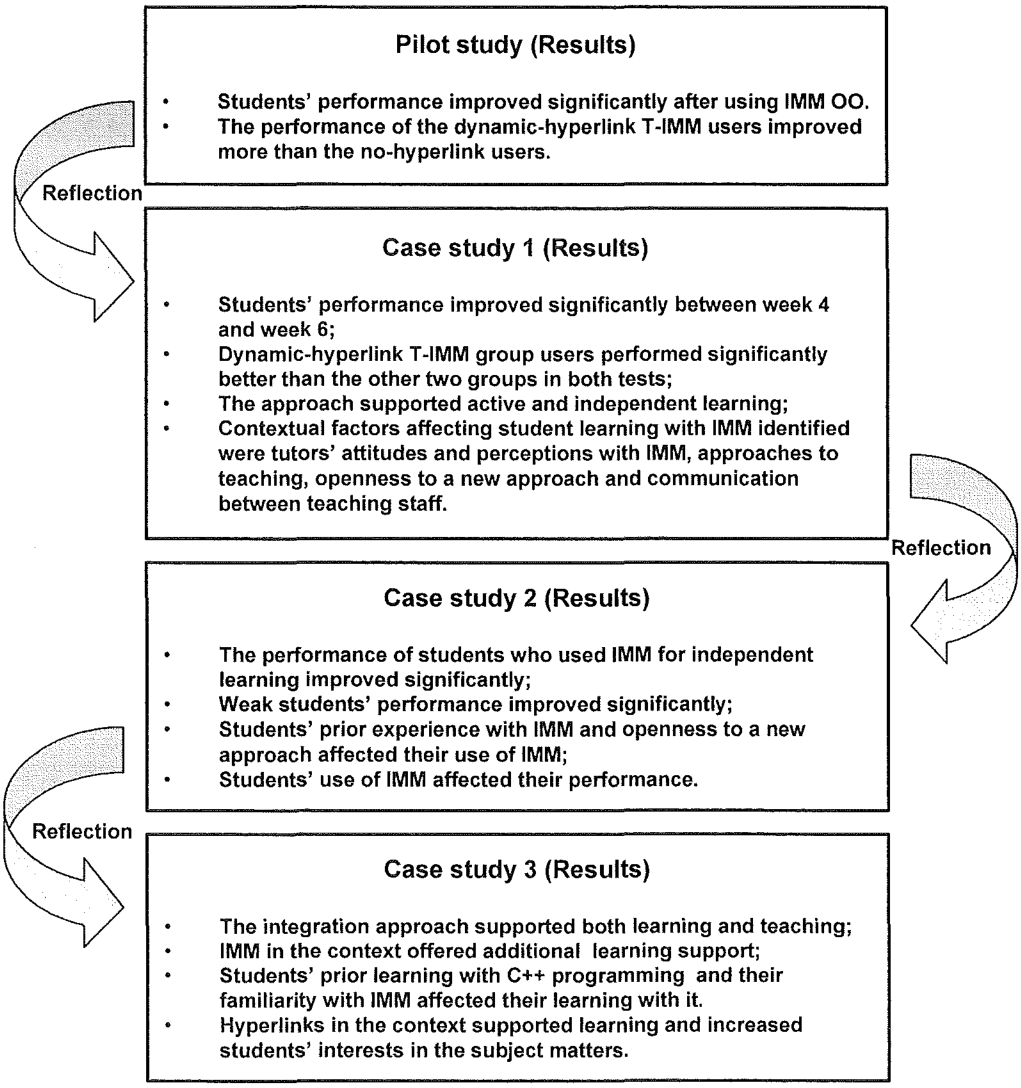


Figure 5-2 Main results from the studies

Case study 2

As presented in Table 5-1, case study 2 was conducted at Brunel University from week 5 until the end of semester 2 of 2000/2001. Preliminary findings from case study 1 were incorporated to better facilitate student learning with IMM C++. The primary aim of this study was to investigate how individual student experience their learning with IMM courseware. One of the main results from this study was weak students, whose performance with C++ programming in the previous semester had been poor, improved their performance significantly. This study is reported in Chapter 7.

Case study 3

Case study 3 is a follow-up study of case study 2. This study was conducted at Brunel University in semester 1 of 2001/2002. IMM OO, used in case study 1, was integrated into two second year programming modules. This study focused on investigating the effectiveness of the integration approach from the lecturer's perspective. One of the main findings was, as illustrated in Figure 5-2, that IMM courseware provided learning support in a wider context. Many new students, direct entry to 2nd year and the students, who had used IMM C++ in the previous semester, used it for independent learning. In addition, the analysis of interviews data revealed that students' background knowledge and their learning strategy used, and their familiarity with IMM courseware affected their approaches to using IMM for learning. This study is reported in Chapter 8.

Relationships between case studies

There are some shared relationships between the preliminary study at Brunel and Napier universities, the pilot study and three case studies. The relationships between them are summarised in Table 5-2.

Variables	**Studies**
Same IMM courseware	Pilot study, Case study 1 & Case study 3
Same module	Preliminary study & Case study 1
	Pilot study & Case study 2
Same student participants	Case study 2 & Case study 3
Same teaching staff	Pilot study, Case study 2 & Case study 3
	Preliminary study & Case study 1

Table 5-2 Relationships between the preliminary study, the pilot study and three case studies

As described in Table 5-2, IMM OO was used in the pilot study, case studies 1 and 3. Next, the preliminary study at Napier University and case study 1 investigated teaching and learning with the same module, the SD 1B, with different course materials – Toolbooks vs. IMM OO. This module was taught by the same teaching staff in both

1999/2000 and 2000/2001. As for case studies 2 and 3, the same students participated in both studies; they used IMM C++ and IMM OO during two consecutive semesters – semester 2 of 2000/2001 and semester 1 of 2001/2002. In addition, *Lecturer B* delivered the programming modules in the pilot study, and case studies 2 and 3.

5.2. Evaluation methods and data analysis

Strengths and limitations of data collected from the empirical study

The empirical study was conducted in actual learning and teaching environments. It was not possible to directly evaluate the learning effects of the IMM courseware in the contexts, or the effectiveness of the integration approach proposed in Chapter 4, for two main reasons. The first was that it was not possible to evaluate the effectiveness of this approach with IMM courseware through comparing paper-based learning vs. IMM-based learning or integrating IMM courseware for both teaching and learning vs. for independent learning because of ethical issues. The second reason was that there were numerous variables affecting student learning from the educational context, and the characteristics and personal situations of the students. How could we determine whether student performance improvement, if found, was as a result of integrating IMM courseware for teaching and learning?

Evaluation and data analysis were focused on the exploration of how students experienced their learning with IMM courseware in their educational contexts. Primarily, the data analysis was focused on exploring whether students' perceptions of learning with programming improved. Secondly, the analysis was focused on identifying what learning support and benefits they considered to have gained from having IMM courseware in lectures and tutorials. And last, the data analysis tried to determine whether students' perceptions were reflected in their performance.

5.3. Pilot study: learning effects and usability assessment of IMM OO

As described in Section 5.1, a pilot study was conducted to evaluate usability and learning effects of the IMM courseware design, proposed in chapter 4, in an actual learning environment. The aims of this study were:

- to assess the usability of IMM courseware;
- to evaluate the learning effects of the courseware;
- to explore the learning effects of hyperlinks in problem-solving contexts.

5.3.1. Object-Oriented Programming module description

The department of Computing and Engineering at Brunel University offered an Object-Oriented Programming (OOP) module to 2nd year Computing and Engineering courses. This module was designed to continue to teach procedural programming from 1st year programming modules and to introduce object-oriented programming with C++. At the time of the pilot study, *Lecturer B* had already begun to teach object-oriented concepts and considered that the integration of IMM OO could be beneficial for the students.

5.3.2. Participants

Twenty six 2nd year students enrolled for the OOP module in semester 1 of 2000/2001 at Brunel University. The participants of this pilot study were 19 students who attended their tutorials in week 10. They had background knowledge of C++ programming from their first year studies with programming modules, but most did not have in-depth knowledge of object-oriented programming concepts and principles.

5.3.3. Courseware: IMM OO and paper-based programming tasks

This study evaluated a prototype of IMM OO – its learning effects and usability. As described in Section 4.5.2. IMM OO consists of two types of IMM materials: a

Resource-oriented material (R-IMM OO) containing resources and a Task-oriented material (T-IMM OO) containing questions and tasks. The prototype of IMM OO used in this study was developed to support an hour's lecture and an hour's tutorial. The topics presented in the courseware were some of the main OO concepts – messages, objects, message passing and etc. T-IMM OO was developed with two variations (Section 4.5.2):

- one with hyperlinks;
- the other with no hyperlinks between R-IMM and T-IMM.

In addition to IMM OO, for the tutorials *Lecturer B* prepared paper-based programming tasks that required students to apply the concepts, message passing and objects, which students were expected to learn from IMM OO.

5.3.4. Study environment

This pilot study was conducted in the classroom learning environment during two 3 hour tutorials in week 10 of semester 1 of 2000/2001 at Brunel University (even though the OOSD multimedia courseware was developed at Napier University.). The main reason for this was that OO concepts were taught in the first semester of 2nd year at Brunel University but in the second semester of 1st year at Napier University. The results from this case study will be used as a basis for the following case studies.

The students used IMM OO in a computer lab as a part of their learning materials during their week 10 tutorials. *Lecturer B*, who was the tutor and module leader, and a demonstrator were present. IMM OO was installed on the university Intranet, and a paper-based programming task was distributed to the students, who were asked to use R-IMM OO first to learn some OO concepts and then to do the tasks in T-IMM OO. The paper-based programming task required a good conceptual understanding of the topics taught in IMM OO. Two versions of T-IMM OO were installed equally on computers, and it was allocated randomly to students.

5.3.5. Research methods

A mixture of quantitative and qualitative research methods was used to collect data and as follows:

Pre-test and post-test

These were performed to determine how much students' understanding (performance) improved, if any, as a result of using IMM OO. Each test contained three different types of questions: one requiring students' understanding of objects, the second objects and messages, and the third message types and message passing process. The difficulties of the questions in both tests were balanced. The summary of the questions is presented in Table 5-3.

	Description of questions
Question 1	▪ Identifying senders & receivers
Question 2	▪ Identifying senders & receiver ▪ Identifying messages ▪ Results of receiving a message
Question 3/ **Question 4 (Post-test only)**	▪ Message passing process ▪ Message types

Table 5-3 Topics asked from the questions in the pre and post tests

A difference between the two tests was that there was one more question for the third type in the post-test to measure how much students' understanding improved. These tests are included in Appendix 4 and 5.

Two questionnaires

One questionnaire was answered at the beginning of the tutorials to gather information about how students perceived their learning with the module and their understanding of the subject. The other questionnaire was answered as part of a usability assessment after the students had used IMM OO, to ascertain students' perceptions of their experience with IMM OO: their perceptions and the benefits of IMM OO in the learning context. The two questionnaires are included together with the two tests in Appendix 4 and 5.

Tracking files

The aim was to record students' interactions with IMM OO, i.e., navigational patterns, their answers to questions in T-IMM OO, how many times they used hyperlinks to access related information to R-IMM and etc,

Interviews with students and teaching staff

Students were interviewed informally after they had finished their post-test and 2nd questionnaire. The interviews with students were mostly to clarify their responses to the questionnaires or their interesting behaviours observed during the tutorials. They were also intended to further explore how they perceived IMM OO for their learning. An interview with the module leader was conducted at the end of the semester to investigate long term effects contributed by integrating IMM OO for the tutorials and using it for independent learning later.

Observations

Student interactions with IMM OO, and between students and tutors were observed. For example, if they used R-IMM OO and T-IMM OO at the same time or separately, how they interacted with their classmates and tutors while using it. Additionally, it was to identify any usability and technical problems students encountered.

5.4. Results: learning effects and usability of IMM OO

Section 5.4.1 and Section 5.4.2 report students' performance before and after using IMM OO and between the two hyperlink treatments. Section 5.4.3 presents the usability assessment results, Section 5.4.4 describes students' interactions in tutorials observed.

5.4.1. Learning outcomes: performance

In order to determine how much student learning, performance and perceptions, improved as a result of using IMM OO, a pre-test and a post-test were performed before and after using IMM OO. The students spent about 20 minutes answering each test; during this time they also answered an accompanying questionnaire. The students spent from 50 minutes to 1 hour and 10 minutes on IMM OO. The mean and Std. Deviation of the time for R-IMM OO was 20.6 and 10.2, and for T-IMM OO 32.2 and 10.8 respectively. Students' marks for the pre-test and post-test are illustrated in Figure 5-3.

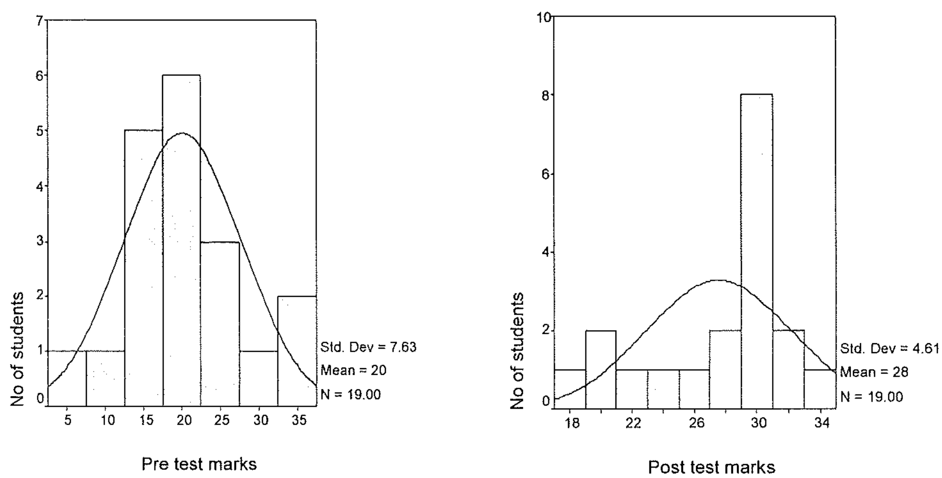


Figure 5-3 Pre-test and post-test results: total =36 (left: pre-test result and right: post-test result)

As the two graphs suggest, student performance between the two tests improved. The mean and standard deviation of the pre-test are 56.7 (%) and 7.6, and for the post-test they were 76.3 (%) and 12.0 respectively. To examine the two tests results more closely, students' performance was compared between each question. The results of each question are presented in Table 5-4.

Question no	Pre-test			Post-test			Improvement
	Mean	Median	Std.	Mean	Median	Std.	
Question 1 (%)	81.1	100	29.9	93	100	14.0	11.9
Question 2 (%)	70.8	66.7	23.8	83	100	23.7	12.2
Question 3 (%)*	**18.2**	**0**	**37.2**	**53**	**71**	**15.7**	**34.8**
Total (%)	56.7		20.9	76.3		12.0	19.6

Table 5-4 Comparison of students' performance between pre-test and post-test results (* the mean of question 3 (mean = 8.4, Std. Deviation = 3.2) and question 4 (mean = 7.8, Std. Deviation = 2.8) of the post test was used)

At the time of this study (week 10) *Lecturer B* expected students to have some understanding of objects and messages (question 1 and 2) as a result of previous teaching, but did not expect them to be able to answer question 3 - message passing and types of messages. As expected, students answered question 1 and 2 in the pre-test well but not question 3. As displayed in Table 5-4, the median of question 3 in the pre-test was 0 although the mean was 18.2 (%). To further explore the result, each student's performance for question type 3 was compared.

		Each student result of pre-test and post-test																		
Pre	Q3	0	0	33	0	0	0	100	17	0	0	0	0	0	0	0	0	0	100	100
Post	Q3	75	33	75	42	92	42	33	58	42	42	58	25	92	42	42	33	42	75	42
	Q4	50	42	83	58	50	50	58	50	40	40	80	50	80	0	60	80	60	60	40

Table 5-5 Each student's performance of question type 3 from the pre-test and post-test

As presented Table 5-5, 14 students got 0 marks out of question 3 in the pre-test, and their performance much improved after learning with IMM OO. To determine whether the improvement between the two tests results was statistically significant, paired samples T test was performed. The distribution for the post test marks was negatively skewed. However, the distribution for both test marks was assumed to be normal (Kolmogorov-Smirnoz $Z = 0.63$; $p = 0.82$ for pre test, and $Z = 0.91$; $p = 0.38$ for post test). The results are summarised in Table 5-6.

Pairs	Paired differences	Std. Deviation	t	Sig. (1-tailed)
Pre Q1 – Post	-1.5	4.3	-1.5	.08
Pre Q2 – Post	-1.5	3.5	-1.8	.04
Pre Q3 – Post	-4.2	4.7	-3.8	.00
Pre tot – Post tot	-7.5	10.1	-3.2	.00

Table 5-6 Results of paired samples T test (*df* = 18)

Students' performance between the pre-test and post-test was found to be significantly improved at 0.01 level (one-tailed *t* test; t = -3.23, *df* = 18). When paired samples T test was performed for each question of the two test results, it was found that students' performance of question 2 and question 3 was improved significantly: question 2 at 0.05 level (t = -1.83, *df* = 18) and question 3 at 0.001 level (- t = -3.84, *df* = 18). As expected, the improvement of the result of question 1 was not significant. These results indicate that IMM OO was effective in supporting students to conceptualise abstract programming concepts. To determine whether the learning, content acquisition at the time of study (students' understanding of the topics in IMM OO), was a lasting one, *Lecturer B* was interviewed at the end of the semester.

Long term learning effects from IMM OO in subsequent learning and teaching

During the interview, *Lecturer B* described that:

> *TK:* Once the message passing was introduced with the IMM courseware, it became easier for students to understand the concept of OO in general and passing messages from objects to objects in particular, especially in practical implementation of a real programme with message communication... In the following several lectures it was easy to communicate with students about message passing and identifying sender-receiver-message in real life in the case of programming.

Excerpt 5-1 Lecturer B's comment on learning effects of IMM OO in subsequent lectures

To determine whether students' experience with IMM OO affected their final exams, their performance and choice of the exams questions were examined. As expected, there was no significant association between students' performance between the post test and the final exam. IMM OO was used for too short time to expect a significant association between them. However, students' choice of the final exam questions was interesting. The final exam consisted of 5 questions. Question 1 was compulsory and, two were selectable. Most students (19/22) chose questions related to OO concepts, and *Lecturer B* during an interview with the module leader cited that: '...I was quite surprised that so many students attempted to answer object-oriented questions...' She reasoned that students' experience with IMM OO contributed to improve students' perceptions of OO.

5.4.2. Students' performance between hyperlink treatments

To determine whether and how effectively providing a means to access information directly to related information in a resource-oriented IMM (R-IMM OO in this study) when students answered questions incorrectly, students' performance between two different versions of T-IMM OO were compared: no hyperlink and dynamic hyperlink versions. As described in Section 5.3.4, the two versions of T-IMM OO were randomly installed on the computers in the tutorial lab. Because this study aimed to evaluate the usability and learning effects of IMM OO in a real learning environment, students' seating was not arranged.

As a result, students were not equally divided between the two versions of T-IMM OO. Seven students used the dynamic hyperlink version of T-IMM OO (dynamic hyperlink group), and 12 used the no-hyperlink version (no hyperlink group). When their performance of the pre-test results was compared, unfortunately it was found not equally balanced. Students' performance between the two groups from the pre-test and post-test are illustrated in Figure 5-4.

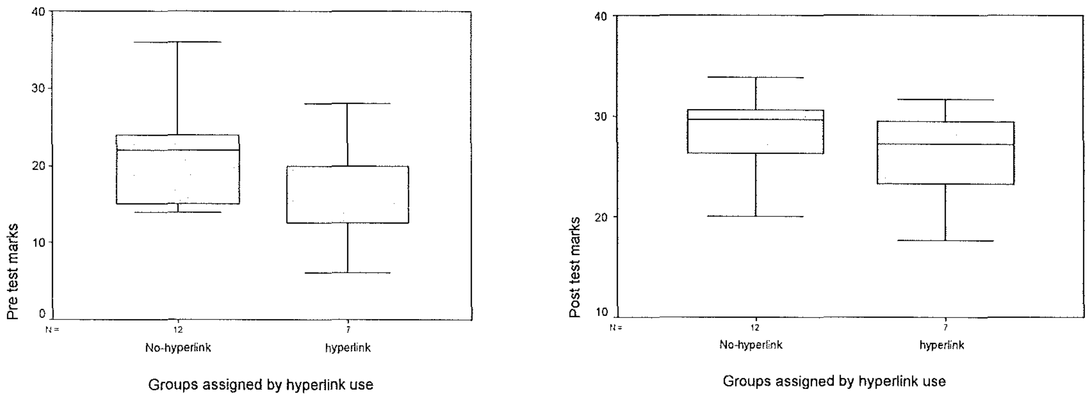


Figure 5-4 Students' performance of the pre-test between no-hyperlink and dynamic hyperlink groups (left) and their performance of the post-test between the two hyperlink groups (right)

The mean and Std. deviation of both groups from the pre-test and the post-test are summarised in Table 5-7.

T-IMM OO types	Tests (%)	Mean (%)	Std. Deviation
No-hyperlink users (no = 12)	**Pre test**	68.2	12.1
	Post test	72.0	12.4
	Improvement	**9.5**	23.9
Dynamic hyperlink users (no = 7)	**Pre test**	47.6	21.9
	Post test	62.5	19.1
	Improvement	**20.5**	31.8

Table 5-7 Students' performance between No-hyperlink version of T-IMM OO users and Dynamic-hyperlink version of T-IMM OO users

As displayed in Table 5-7, the mean and Std. deviation of the no-hyperlink group from the pre-test are 68.2 (%) and 7.6, and for the dynamic hyperlink group 47.6 (%) and 7.6 respectively. From the post-test, the mean and Std. deviation of the first group were 72.0 (%) and 4.2 and of the second group 62.5 (%) and 5.3 respectively. Although the first group (No-hyperlink T-IMM OO version users) still performed better in the post-test, the second group (Dynamic-hyperlink IMM OO version users) improved 11% more from the post-test than the first group.

To determine whether the higher improvement of students' performance in the second group was caused by their use of the dynamic-hyperlink T-IMM OO version, their records from tracking files were compared with the no-hyperlink group. As described in Section 5.3.4, in the beginning of the tutorials students were asked to use R-IMM OO first to study OO concepts and then to answer questions (open questions) in T-IMM OO. Although students were asked to use IMM-OO for the time assigned (about for an hour), no restriction was given to how they could divide their time between R-IMM OO and T-IMM OO. The data from the tracking files revealed that students divided their time between the two materials differently. For example, some students spent a much longer time with T-IMM OO than R-IMM OO. When students' records were compared between the two T-IMM OO version users, the dynamic-hyperlink version users used R-IMM OO longer than the no-hyperlink version users. When they revisited R-IMM OO from T-IMM OO, they not only accessed the content page but navigated to other pages as well. To determine whether the duration of students using either R-IMM OO or T-IMM OO, was associated with their performance improvement between the two tests, correlation tests were performed. A significant positive association was found between the duration of time with R-IMM OO and the students' performance improvement at 0.05 level ($r = +0.81$).

However, there did not appear to be an association between the improvement of students' performance between the two tests and the duration of their using T-IMM OO. This result and the 11% higher improvement of students' performance between the two T-IMM OO versions users may indicate that hyperlinks provided as part of feedback with questions in T-IMM OO encouraged students to revisit related information in R-IMM OO to clarify their misunderstanding, and as a result their understanding improved. Students' responses to the two questions about hyperlinks helped their learning in the post-questionnaire suggested that the 11% higher performance improvement in the dynamic hyperlink version users could be as a result of their revisiting R-IMM OO with hyperlinks from T-IMM OO[2].

For the question 'hyperlink being very useful for problem solving', 5 students agreed and one answered neither. For the question 'direct access to information having helped their understanding', all students agreed. One more question for 'possibility of direct access to information helping understanding' was answered by 7 students, and all responded positively. The question was aimed for all participants to answer but because this was located after two hyperlink related questions, only one more student answered it. He commented that: 'Would be interested in this feature.' Case study 1, as will be reported in Chapter 6, further investigated learning effects of hyperlinks for learning.

5.4.3. Usability of IMM OO

After using IMM OO, students answered the second questionnaire with the post test. This was aimed to ascertain their learning experienced with IMM OO. Eighteen students answered the questionnaire because one was not aware that a questionnaire was included in the post test. Students' responses revealed that most considered their experience with IMM OO positively. Students' responses are summarised in Table 5-8.

Questions	**SA**	**A**	**N**	**D**	**SD**	**Total**
a. I found this application *easy to use*.	10	8				18
b. I *enjoyed* using application.	7	8	2	1		18
c. I now have *a good understanding of messages and objects*.	10	6	1			17
d. The *animations helped me understand* the subject better.	12	5			1	18
e. The extra features (help, glossary) were helpful.	1	9	3			13
f. I felt in *control of my learning* at all times.	7	8	2		1	18
g. I would *like to use more interactive multimedia* learning applications like this.	13	4		1		18
h. I *will use this application when revising*.	4	9	3	1	1	18
SA: strongly agree, A: agree, N: neither disagree nor agree, D: disagree, SD: strongly disagree.						

Table 5-8 Students' responses from usability assessment questions after using IMM OO

[2] The two questions were answered by 6 students, who used 'Dynamic hyperlink version' of T-IMM OO.

Good understanding of the topics, messages and objects from IMM OO

All except one students responded positively to the question 'c. now I have a good understanding of the messages and objects'.

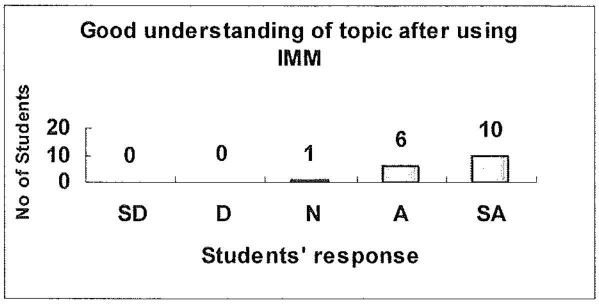


Figure 5-5 Students' responses to having a good understanding of the topics in IMM OO after using it

The student, who did not agree to the question, prior to using IMM OO expressed his poor understanding of OO and needs for help. The student commented on his learning difficulties with the subject matter as follows;

> *BP00S1*: I find it *difficult to grasp the basic concepts*; reading texts appear to help in theory, but *when a practical situation comes, it is useless*. .... I have similar problems with C++ but OO is more confusing...... I think I need more guidance on '*How to study programming.*' I find it really difficult and I don't really know where or how to start ....

Excerpt 5-2 A student's comment on the difficulties of OO

After using IMM OO, he cited using IMM courseware as: 'Very good format of learning for new users.' His comment after using IMM OO implies that he found IMM OO beneficial for his learning. Also, his performance between the pre-test and post-test was much improved. This may suggest that the architecture and content design of IMM OO are effective in supporting weak students in the understanding of programming concepts.

Enjoyed using IMM OO, control of learning, and more IMM in future

Most students' responses to the questions were very positive. Data from three questions, i.e. 'b. enjoyed IMM OO', 'f. felt control of learning' and 'g. more IMM in future' suggested that students' responses to them could be related. As most students' responses were positive, it was difficult to determine whether they were related or not. However, negative answers for the three questions came from the same students. When a student, who answered to all three questions negatively, was interviewed, he cited that:

> *BP00S2*: I enjoyed using the application...but asking too many basic things...Would be nice if the story could develop further.... It could be more interesting *with hardest questions* about programming.

Excerpt 5-3 A student's comment on wanting to have more difficult question in IMM OO

As the student reasoned, IMM OO was helpful for the learning of fundamental OO concepts, but it did not have enough resources or difficult tasks to suit advanced students. For the same reason 2 students' disagreed with the question 'will us IMM OO when revising'. A student cited that: "Too simple material to revise, but if more difficult I will."

Comparisons were made between students' responses to the questions in the post questionnaire and their performance from the pre-test and post-test to determine if students' perceptions of their learning experience with IMM OO was related to their performance. Students, who strongly agreed to the questions 'b. enjoyed using IMM OO' and 'c. have a good understanding of messages and objects', improved much more than others. The mean was higher more than 5. This was not surprising as students who used R-IMM OO for a longer time performed significantly better.

Animation helping understanding

When the records of tracking files were analysed, all students repeatedly played animations in IMM OO. The mean of students playing animations was 20.6 times (about 12 simple animations), and some played them as many as 34 times. As illustrated in Figure 5-6, apart from 1 student all agreed that the animations in IMM OO helped them understand the concepts.

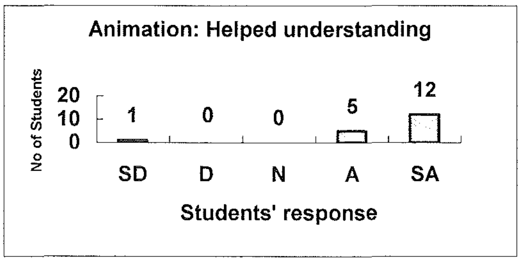


Figure 5-6 Students' responses to animation in IMM OO helped understanding

When the student was asked whether she had considered the animations in IMM OO were not helpful or animations in general, she replied:

> *BP00S3*: Only in this application because the concepts were very easy to understand... *I already knew the OO concepts.* So, the animation did not really improve my understanding. But normally, I find animation helpful for my understanding.

Excerpt 5-4 A student's comment on why not considered the animation in IMM OO helpful

Easy to use and extra features helpful

All 18 students considered IMM OO easy to use, and in terms of 'extra features' in IMM OO, most students (10/13) considered the extra features helpful for their learning. Five students responded with "N/A" because they did not use the features.

5.4.4. Student interactions with IMM OO and their tutors

Students' learning with IMM OO vs. paper-based programming tasks

After using IMM OO students were asked to do a programming task – implementing objects, messages and message passing with C++. Some students did the task actively, but many were sitting in the lab together with other students without even attempting to do the task. When they were asked about this, they replied that they did not know where to start.

Students' interesting interactions with IMM OO

There were some interesting patterns of the students' approach to using IMM OO. As this study was conducted only during two tutorials, the findings here were not supported by solid evidence. Students' interesting behaviours were from observation and tracking data, and these need further investigation in the future studies.

Firstly, observation showed that most students read the objective and summary of each lesson. They paid much attention to the content structure presented on the menu page – going over each main topic, checking their sub-topics and visiting the menu several times. Secondly, in general students navigated linearly within a lesson material. But when the students visited the material through hyperlinks, they did not only study the page led by the link but they also read relative topics as well. Also, they seemed to pay more attention to the content and played animations more. Thirdly, it was noted that some students answered questions in the task-oriented material more than once. One reason seemed to be that students were answering the questions till they were satisfied with their answers. The impression the author got was that the students were willing to study when they knew where to get the information required and could get their own answers easily from the courseware. Many showed a reluctance to asking help of their tutor when they knew little about the tasks given. Much more investigation is required.

5.5. Summary

This pilot study, reported in this chapter, focused to evaluate learning effects and usability of IMM courseware. IMM OO was introduced as a part of tutorial materials during two 3 hour tutorials, and students used them in their tutor's presence. Before and after using the courseware students answered 2 questionnaire surveys and took two tests. The results of two tests and 2nd questionnaire revealed that using IMM OO significantly improved students' performance and perception of understanding OO concepts. Another to notice in terms of students' performance is that students' performance with hyperlink version was improved more than ones with no-hyperlink one although the difference was not statistically significant.

However, the correlation found between how long students' used R-IMM OO and the improvement in their performance suggests that students accessing information to clarify their understanding may facilitate learning more effectively than providing a model answer with search facilities. This will be further investigated in case study 1.

CHAPTER 6 CASE STUDY 1: HYPERLINK EFFECTS & GROUP LEARNING SUPPORT WITH IMM OO

Comparison of students' performance between a pre-test and a post-test in the pilot study, reported in Section 5.4.1, showed that as a result of learning with IMM OO in one tutorial students significantly improved their understanding of object-oriented concepts. Both their performance and perceptions of the subject matter improved. This result suggests that the architecture and design features of IMM OO are effective in facilitating students' learning with the subject matter. In addition, analysing the lecturer's teaching experience in the following lectures and the students' choice of their final exam questions revealed that the students' learning experienced with IMM OO positively influenced their subsequent learning with the module.

However, these results are insufficient to determine the effectiveness of the design and integration approach, proposed in Chapter 4, as the students in the pilot study used IMM OO for a short duration of time. To further investigate the effectiveness and efficacy of the design and integration approach, 3 case studies were conducted in real teaching and learning contexts. In the case studies IMM courseware were integrated into lectures and tutorials for longer durations of time.

This chapter reports the 1st case study conducted at Napier University in the 2nd semester of 2000/2001 academic year. IMM courseware (IMM OO), which was further developed after the pilot study, was integrated into a programming module and used in lectures and tutorials from week 1 until week 6. For the rest of the semester, it was kept on the university Intranet to continue to support independent learning.

After posing research questions this study aimed to answer, Section 6.3 describes the participants, the study environment including the description of the module, the IMM courseware used and its integration with other materials into the curriculum, and the research methods used. Section 6.4 describes data collected. Section 6.5 reports results from this study. The results are reported in two main areas: the effects of the integration of IMM courseware and the hyperlink effects on students' performance and their perceptions of learning with the subject matter. Having reported the results, Section 6.7 summarises main findings of this study and identifies areas to be investigated in the following case studies.

6.1 Aims of the study

This study had two main aims. One was to evaluate the effectiveness of the integration approach through examining students' performance and exploring how students experienced and perceived their learning with IMM courseware. The other was to continue to investigate the learning effects of hyperlinks in problem-solving contexts. In particular, it was aimed to explore how hyperlinks support the learning process when IMM courseware is used in both lectures and tutorials.

6.2 Research questions

This study aims to answer the following questions.

- Does the integration of IMM courseware bring a change in students' perceptions and performance with the subject matter they are studying?
- Does using IMM courseware in tutorials increase interactions and dialogue between students, and between students and tutors?
- Between providing hyperlinks with questions and providing them as part of feedback after students answered incorrectly, what works more effectively in supporting the learning process?
- What factors affect student learning with IMM courseware?
- What are the benefits of integrating IMM courseware for both teaching and learning?

6.3 Methods

6.3.1 Participants

The participants of this study were 177 1st year students who enrolled for Software Development 1B module (SD 1B) and the teaching staff of this module. The total number of students who participated in 2 questionnaires and 2 tests were 105.

6.3.2 Software Development 1B module description

School of Computing at Napier University offers the Software Development (SD) 1B module to a large number of 1st year students from many Computing and Engineering courses. This module aims to teach object-oriented software development with Java. Students who enrol this module are expected to have some background knowledge of Java programming as this module is offered in semester 2 and students need to take the Software Development 1A with Java programming as the prerequisite of this module in semester 1. Because the class size of this module is normally large, it is delivered by team teaching. In semester 2 of 2000/2001 when this study was conducted, the lectures were delivered by *Lecturer N* and the tutorials (lab sessions) were supported by *Lecturer N* and 4 other teaching staff.

6.3.3 IMM courseware (IMM OO) integration into the curriculum

IMM courseware (IMM OO)

IMM courseware (IMM OO), described in Section 4.5.2, was originally designed for this module based on the requirements identified from the preliminary study (Chapter 3). To evaluate the usability and learning effects of IMM OO, a prototype was developed and with it a pilot study was conducted at Brunel University (Chapter 5). Findings from the pilot study were then incorporated into further development of IMM OO, which was developed to support 5 weeks of lectures and tutorials. The architecture of IMM OO was composed of: a Recourse-oriented IMM material (R-IMM OO) containing 7 lecture units, and a Task-oriented IMM material (T-IMM OO) containing 7 tutorial units. T-

IMM OO was developed with three variations to investigate the learning effects of hyperlink in problem solving contexts. The three variations were:

- No-hyperlink version: only a model answer was provided as feedback in T-IMM OO. 'Search', 'menu' and 'glossary' facilities were available in R-IMM OO.
- Static-hyperlink version: hyperlinks, providing direct access to related information in R-IMM OO, were provided with questions and tasks. Students could still use 'search', 'menu' or 'glossary' facility in R-IMM OO.
- Dynamic-hyperlink version: hyperlinks were provided with a model answer as part of feedback either after students answered multiple choice or fill-in questions incorrectly or after they completed design tasks or open-ended questions.

Apart from hyperlinks embedded differently, all three variations of T-IMM OO had exactly same content and design features as they were developed as part of course materials. From the tutorial unit 5 in T-IMM OO, students needed to use a modelling tool for design tasks. A UML modelling tool (ROME), described in Table 6-1, was integrated into T-IMM OO so that students could run ROME to do the design tasks and at the same time they could get feedback on their solution and access related information in IMM OO.

Integration with other course materials and tools, and module delivery

IMM OO was integrated with other course materials and tools, and the roles and descriptions of the course materials are summarised in Table 6-1.

The booklet, co-authored by *Lecturer N* and another tutor, and IMM OO were the main learning materials for SD 1B module. It was aimed for students to construct fundamental understanding of object-oriented design and programming with IMM OO and to build in-depth knowledge with the booklet.

Materials	Role	Description
SD 1B booklet	Learning materials	This booklet was co-authored by *Lecturer N* and Tutor JS, and contained detailed information of software development processes including UML, Java programming and etc.
Paper-based programming tasks	Tutorial materials	They were composed of separate units and each unit contained programming tasks assigned for one tutorial. They were used from semester 1 as SD 1A and SD 1B were co-requisite modules. They were used in tutorials with T-IMM OO.
IMM courseware (IMM OO)	Teaching and learning materials	IMM OO was developed to assist teaching and to support students' learning. IMM OO was developed for the first 5 week lectures and tutorials due to time constraints.
ROME	A modelling tool	ROME was an object-oriented modelling tool, which was developed to support students' OO design and programming with C++ and Java. The primary strength of this tool is that it generates Java/C++ programming code automatically from a model (class diagram) illustrating the links between the model and programming code generated.
Microsoft Office	Tools for lectures after week 5	IMM OO was not developed for the whole semester due to time constraints of *lecturer N* at the time of study. From week 6, *Lecturer N* used a combination of Microsoft Word, PowerPoint and ROME in lectures.

Table 6-1 Course materials and tools for SD1B

IMM OO: integration into the curriculum

The module structure and course materials are summarised in Table 6-2.

Component	Week 1 – week 5	Week 6 – Week 15
Lecture	R-IMM OO	Lecture materials were created and delivered during lectures with PowerPoint, Microsoft Word, ROME and etc.
Tutorial	▪ T-IMM OO ▪ Paper-based programming tasks ▪ ROME	▪ Programming tasks ▪ ROME ▪ Java compiling tool
Learning	IMM OO, SD 1B booklet, and ROME	

Table 6-2 Integration of IMM OO into the curriculum

As displayed in Table 6-2, IMM OO was used for both lectures and tutorials. For the first 5 weeks IMM OO was used in lectures to teach object-oriented concepts and design. After week 5, lectures were delivered with PowerPoint, Microsoft Word or ROME illustrating programming concepts and demonstrating programming processes;

Lecturer N used the tools in the place of a blackboard to write and to draw simple diagrams during lectures. As for tutorials, students had the paper-based Java programming tasks, IMM OO and the booklet. In the first tutorial, students were asked to do the programming tasks after finishing the tutorial units in T-IMM OO assigned for each tutorial.

Allocation of the three variations of T-IMM OO to 5 tutorial groups

Two 1 hour lectures per week were scheduled and they were delivered by *Lecturer N* on Monday and Friday, and for tutorials (lab sessions), students were divided into 5 groups. The timetable, tutors allocated and T-IMM assigned to the tutorial groups are summarised in Table 6-3.

Tutorial group	Timetable	Lecturer/Tutor	T-IMM version
A	Monday 11:00 – 13:00	*Lecturer N* & demonstrator F	No-hyperlink version
B	Monday 15:00 – 17:00	Tutor B	Dynamic hyperlink
C	Tuesday 10:00-12:00	Tutor C & demonstrator N	Static hyperlink
D	Tuesday 11:00-13:00	Tutor D & demonstrator F	Dynamic hyperlink
E	Wednesday 13:00-15:00	Tutor E & demonstrator F	Static hyperlink

Table 6-3 Timetable and tutors allocated for each group

Group B was the smallest tutorial group, and this group had part-time and elective students. Initially, a tutor and a demonstrator were assigned to each group, excluding Group B; however, Demonstrator N took charge of Group C from week 4 as Tutor C could not come back to work due to illness. This by accident affected students' use of T-IMM OO in tutorials and as a result, their performance from test 2 (see Section 6.5.3). As presented in Table 6-3, the three variations of T-IMM OO, described in the beginning of this section, were assigned to the 5 tutorial groups with *Lecturer N*'s permission. The only consideration given for allocating the three variations of T-IMM OO to the 5 groups was balancing the number of students for the three variations. The three variations of T-IMM OO were assigned as below:

- no-hyperlink version to tutorial group A;
- static-hyperlink version to tutorial group C and E;
- dynamic-hyperlink version to tutorial group B and D.

6.3.4 Research methods

A mixture of qualitative and quantitative methods was used to investigate teaching and learning experienced with the integration of IMM OO for both teaching and learning of the programming module. The methods used and their aims are described in this section.

Two tests

Two tests, included in Appendix 6 and 7, were performed to compare students' performance between three T-IMM OO versions and to determine if and how integrating IMM OO into the curriculum affected students' performance. Both tests and model answers were produced by *Lecturer N*, and they were marked by the author based on the criteria set by *Lecturer N*. Each test contained an analysis and design task with the same level of difficulties, and the task required students' understanding of object-oriented concepts and applying them in designing with UML. Test 1 was performed in the week 4 tutorial, and test 2 in the week 6 tutorial. The time allocated for each test was about 20 minutes, and both tests were supervised by the teaching staff of each tutorial group and observed by the author.

Data from the tests were then analysed comparing students' performance between the two tests, 5 tutorial groups and the three hyperlink groups divided by the variations of T-IMM OO. The results from the tests were also analysed with the students' academic performance of SD 1A and SD 1B modules.

Questionnaires

Two questionnaires, included in Appendix 8 and 9, were designed to ascertain students' perceptions with and attitudes towards their learning with IMM OO in the learning context. The first questionnaire was answered at the end of week 2 and second at the end of week 13.

Tracking data

IMM OO was programmed to create a tracking file naming it with the user's login ID and the type of IMM OO they used. For example, if a student used the dynamic-version of T-IMM OO, then the file name would contain the user ID and "tutorial-dy". A tracking file stored information such as the date and time of IMM OO used, a record of students' answers in T-IMM OO, the navigation path and the duration for each page, the number of times animation was played and hyperlinks were used, and etc. For the same user, it was programmed to open the existing file and add a new record. At the end of each tutorial, tracking files were collected. Additionally twice a week tracking files were collected from all computer labs because many students used IMM OO for their independent learning in several computer labs.

Interviews with students and teaching staff

Students' were interviewed in tutorials during the first 6 weeks. Formal interviews with students were scheduled after 2nd questionnaire. However, the 2nd questionnaire was postponed due to the module schedule until the end of the semester, and at the time most students were busy doing their coursework or preparing for their final exams. Because of the situation, it was not possible to arrange interviews with students. However, interviews with teaching staff were conducted as planned. Free structured interviews were used to ascertain how tutors experienced IMM OO in the learning and teaching processes.

Observations

Observations were conducted in lectures and tutorials with consent from *Lecturer N* and other teaching staff. Observations in tutorial were focused on observing students' interactions with IMM OO, and their interactions with peer students and tutors. Secondly, tutors' attitudes and support with IMM OO and the paper-based programming tasks were observed and recorded. Thirdly, students' attendances and the atmosphere in each tutorial were recorded. In week 1, the author attended all tutorials to oversee unseen technical problems. From week 2, tutorials for three tutorial groups were observed: group A with no-hyperlink version, group B with dynamic, and group E with static one. Observations in lectures were conducted to observe how *Lecturer N* used IMM OO and students' responses to it.

6.4 Data collected

Quantitative data collected from this study is summarised in Table 6-4. Among 123 students who finished the module, 105 students participated in the questionnaires or the tests.

Method	Questionnaire 1	Questionnaire 2	Test 1	Test 2
Total	59	18	61	50

Table 6-4 Research methods used and data collected

In addition to the quantitative data listed in Table 6-4, qualitative data was collected from interviews with students and teaching staff: observations data from tutorials for 6 weeks and from lectures for one semester; and a large number of tracking data.

6.5 Results

This section reports the effects of the design and integration of IMM OO on students' performance. How the integration of IMM OO affected students' performance will be discussed in Section 6.5.1. How the hyperlink designs implemented in the Task-oriented

IMM OO (T-IMM OO) will be presented in Section 6.5.2. In addition, the learning supports from the integration of T-IMM OO in tutorials will be discussed in Section 6.5.3. Finally, how much tutors' learning supports with IMM OO in tutorials influenced students' learning experienced and their performance will be reported in Section 6.5.4.

6.5.1 Students' performance supported by IMM OO in lectures and tutorials

To investigate whether integrating IMM OO for both teaching and learning in a longer period of time can facilitate students' learning, two tests were performed in week 4 and week 6. As described in Section 6.3.4, both tests were designed by the module leader, *Lecturer N*, and each contained an analysis and design task that consisted of three sub-tasks. Each test was performed in tutorials, and they were supervised by the teaching staff. The time allocated for each test was 20 minutes, and the total mark for each test was 50. Test 1 was taken by 60 students, and test 2 was 52. There were a few students who performed in one test only, and data was analysed in two ways: one including these students and the other excluding them. From the results of both analyses, no significant difference was found. As this study aimed to investigate the learning effects of IMM OO in the educational context for students as a group rather than individuals, the results from the data analysis including these students were reported.

Object-oriented software design was introduced to students for the first time and students were assumed to have no prior knowledge of it. Students' responses to Question 1 from questionnaire 1 proved it to be true. The majority of students (52/59) cited that they did not have an experience of studying a relevant subject matter. In addition, 95% of the students, who took the two tests, were new to the subject matter. Based on these, students' prior knowledge of the domain was excluded in the subsequent analysis of students' performance from the two tests and their academic performance at the end of semester 2 as one of the variables that affect students' learning.

Two test results

The results from the two tests are illustrated in Figure 6-1.

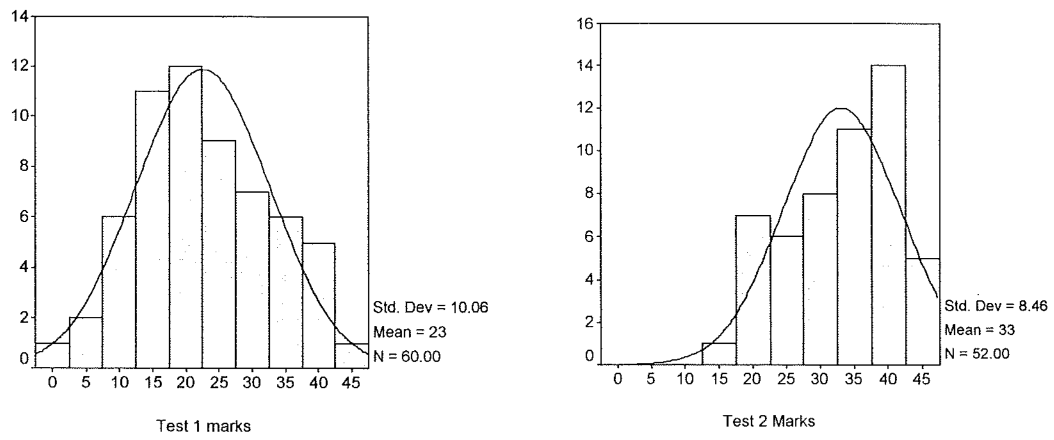


Figure 6-1 Students' performance from the two tests (total marks = 50)

The mean and Std. Deviation of students' performance from test 1 in week 4 were 45.2 (%) and 20.2, and of test 2 66.3 (%) and 16.9 respectively. Examining students' solutions for the task in test 1 suggested that many students grasped fundamental understanding of object-oriented concepts and were able to apply them in designing with UML. At this stage it was not possible to determine whether the integration of IMM OO in lectures and tutorials facilitated students' learning with the subject matter more effectively than traditional methods.

To further investigate how much students' learning with IMM OO in lectures and tutorials contributed to their understanding, 2nd test was performed after 2 weeks. Students' performance from test 1 was compared with their performance from test 2. As Figure 6-1 shows, all students' performance improved at least 30 (%) in test 2. To determine whether the improvement was statistically significant, T-test was performed

(The distributions of both tests were found normal). The results are displayed in Table 6-5. The improvement of students' performance between the two tests was found to be significant at 0.001 level (t=5.8; *df*=110).

	N	Mean	Std. Deviation
Test 1(%)	60	45.2	20.2
Test 2(%)	52	66.3	16.9

Table 6-5 Comparison between students' performance between test 1 and test 2

This result suggests that the integration of IMM OO in lectures and tutorials was effective in supporting students' learning with the module. To investigate the effectiveness of integrating IMM OO in lectures and tutorials for students' learning, further analysis was carried out.

Students who used IMM OO for learning, either in tutorials or for learning between week 2 and week 6 were identified from tracking data. To determine whether their learning with IMM OO affected their academic performance of the module at the end of the semester, students were divided into two groups: IMM OO user group and IMM OO none user group (they may have used IMM OO later for independent learning, but no record was found between week 2 and week 6). ANOVA test was performed between the two groups, and the result is summarised in Table 6-6. It was found that the students, who used IMM OO between week 2 and week 6 in tutorials or for learning, performed significantly better in their final module assessment than ones who did not (F = 17.2, p>0.001).

Use of IMM OO	N	Mean	Std. Deviation
IMM OO user group	74	68.0	22.4
IMM OO none user group	49	51.8	19.4
Total	123	61. 6	22.7

Table 6-6 Performance between the users and non-users of IMM OO in tutorials or for learning

It was considered that if students using or not using IMM OO affected their performance of the final module assessment, the two tests results could be associated to it as well. As IMM OO only contained object-oriented concepts and design with UML and the module assessment included implementation of programming, the association was not expected to be strong. Correlation tests were performed between the two tests results and students' performance from the final module assessment. As Table 6-7 shows, a significant correlation was found between students' performance from test 2 and their module performance at 0.001 level.

Tests	N	Correlation (r)	Significance
Test 1	54	-0.2	0.08
Test 2	46	0.48	0.001

Table 6-7 Correlation test results between SD 1B final assessment marks and two tests[3]

So far three evidences, indicating IMM OO in the context influenced students' learning, were found, and they are: 1) the significant improvement of students' performance between the two tests, 2) the association between students' use of IMM OO and their academic performance at the end of the semester, and 3) the correlation between the students' performance of the two tests and their final module. These three results point that the integration of IMM OO in lectures and tutorials not only supported students' learning of the subject matter at the time of its use but it had also a lasting effect on students' performance. This could mean that with IMM OO in the educational context students came to a 'deep' learning, and this subsequently influenced their performance of the final module assessment.

As discussed in Section 2.1.1, 'deep' learning is closely associated to 'understanding'. And students' intrinsic motivations to learning and their interests in a subject matter

[3] Six students from the two tests did not have final module marks, so they were excluded in the correlation test.

influence how they approach to learning, either a 'deep' or a 'surface' approach. Data was further analysed to investigate if and how IMM OO in the learning context supported students' *understanding* of the subject matter. Results will be continuously reported in next section. Also, data was analysed to explore if the integration of IMM OO helped students perceive their learning positively with the subject matter. Results will be reported in Section 6.6.

More evidence of how much using R-IMM OO and T-IMM OO in tutorials supported learning was found from analysing students' performance between tutorial groups. This is reported in Section 6.5.3.

6.5.2 Learning effects of hyperlinks in problem-solving contexts

T-IMM OO was developed with three different variations and assigned to 5 tutorial groups to evaluate learning effects of hyperlinks as part of feedback in problem solving contexts. Three variations of T-IMM OO evaluated and the tutorial groups assigned are:

- no-hyperlink version to Group A (no-hyperlink group);
- static-hyperlink version to Group C and E (static-hyperlink group);
- dynamic-hyperlink version to Group B and D (dynamic-hyperlink group).

As the name implied the no-hyperlink version did not have any hyperlinks embedded in T-IMM OO, but students could use 'search' and 'glossary' facilities to search information in R-IMM OO. In the static-hyperlink version, hyperlinks were embedded with questions and tasks to help students access related information to articulate their own solutions before answering the questions. In the dynamic-hyperlink version, hyperlinks were displayed as part of feedback when students answered incorrectly or after they did design tasks or answered open questions. It was aimed to help students clarify their understanding or correct misconceptions. The effectiveness of the three versions was evaluated through comparing students' performance between the 5 tutorial groups.

As described in Section 6.5.1, object-oriented paradigm was new to most students, so their background knowledge of the subject matter was not expected to influence their learning of this module. However, it was considered that students' learning experienced with SD 1A in the previous semester could affect their approaches to learning with this module. For example, their confidence or interests in programming gained from SD 1A module could affect their approach to learning with this module, object-oriented design with Java programming, either actively or passively.

Before investigating how the three variations of T-IMM OO affected students' learning, students' performance in the three groups from test 1 and 2 was compared with their academic performance from SD 1A module. The aim was to determine whether the two tests results were contributed by their prior experiences with programming rather than by the differences of hyperlinks design implemented in T-IMM OO. Pearson's correlation test was performed between students' performance from SD 1A module and from the two tests. There did not appear to be a significant association either in students' performance between SD 1A and test 1 ($r = -0.1$; $p=0.35$), or between SD 1A and test 2 ($r=0.3$; $p=0.07$).

The results from the Pearson's correlation tests between SD 1A and the two tests indicated that if there were differences in students' performance between the three hyperlink groups, then they were contributed by the interventions of different hyperlinks design in T-IMM OO.

Students' performance with three different variations of T-IMM OO

Students' performance of test 1 is presented in Figure 6-2. The mean and Std. Deviation of the no-hyperlink group were 36.4 (%) and 16.8, of the static-hyperlink group were 44.0 (%) and 24.0, and of the dynamic-hyperlink group were 55.2% and 18.0 respectively.

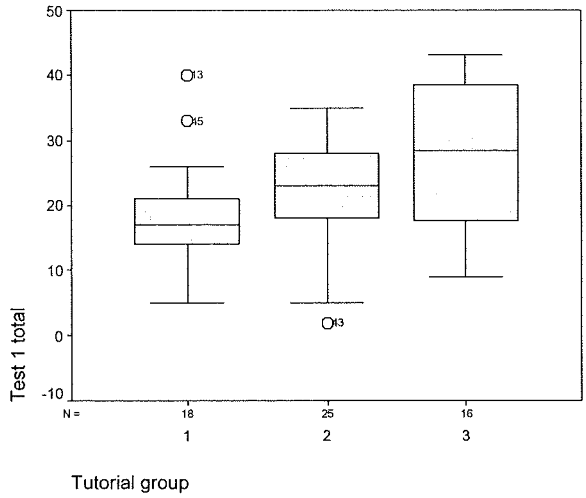


Figure 6-2 Students' performance between three different variations of T-IMM OO (1 = no-hyperlink (n = 18), 2 = static-hyperlink (n = 25), and 3 = dynamic-hyperlink version (n = 16))

To determine whether the students' performance between the three groups significantly differed, ANOVA test was performed. The test result showed that the difference in the students' performance between the three groups was significant at 0.02 level (F = 4.1; *df*=2). Between the dynamic-hyperlink group and the others, the significance was at 0.005 level, and between the static-hyperlink and the no-hyperlink versions, the significance was at 0.016 level. To investigate whether the three different variations of T-IMM OO continued to affect students' performance, test 2 results were examined. The test 2 results are illustrated in Figure 6-3.

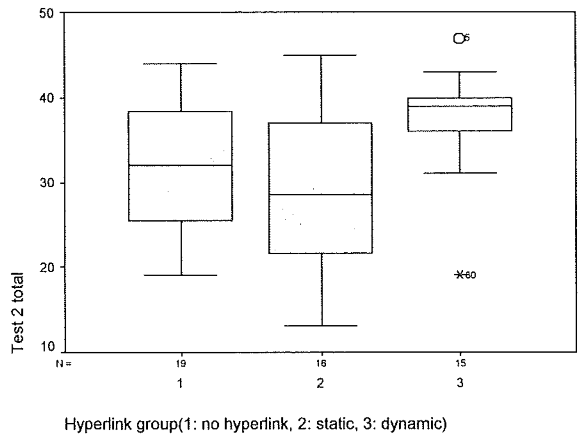


Figure 6-3 Students' performance of test 2 results between three groups (1= no-hyperlink (n = 19), 2 = static-hyperlink (n = 16), and 3 = dynamic hyperlink version (n = 17))

The mean and Std. Deviation of the no-hyperlink group were 64.2 (%) and 16.2, of the static-hyperlink group were 57.8 (%) and 18.0, and the dynamic-hyperlink group were 75.2 (%) and 12.6 respectively. The performance of the dynamic-hyperlink group was still higher than the other two groups. However, in test 2 the no-hyperlink group performed better than the static-hyperlink group. To identify what contributed to this result apart from the three variations of T-IMM OO, the learning situation of this group was further investigated. One of main reasons identified was that Group B, one of the static-hyperlink groups, did not use IMM OO in week 4 and 5 tutorials. This will be further discussed in next section.

To determine whether students' performance from test 2 still significantly differed between the three groups, ANOVA test was performed. The test result revealed that the performance of the dynamic-hyperlink group was significantly higher than the other two groups at 0.01 level ($F=5.2$; $df=2$). However, the difference between the no-hyperlink and static-hyperlink groups did not appear to be significant ($p=0.15$). Test 1 and test 2 results between the three hyperlinks groups are illustrated in Figure 6-4.

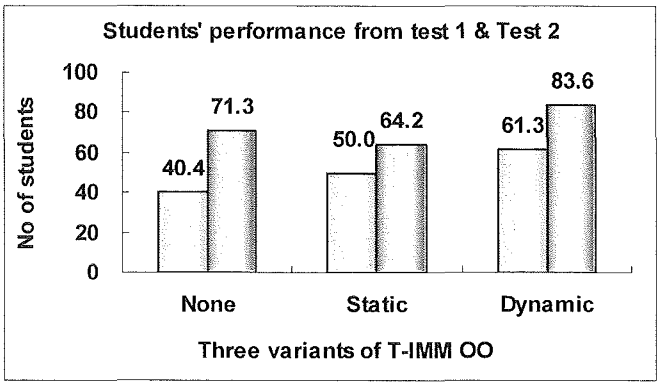


Figure 6-4 Students' performance between three variations of T-IMM OO in test 1 and test 2

To determine whether the three variations of T-IMM OO affected students' learning constantly, Pearson's correlation test was performed between students' performance from test 1 and test 2. There appeared to be a strong association between the results of test 1 and test 2 ($r=0.61$; $N=30$; $p<0.001$). This suggests that students' performance from the two tests was not obtained by chance and the three different variations of T-IMM OO affected students' learning in the same way continuously.

The results from the two ANOVA tests between the three hyperlink groups and the correlation between the two test results suggest that the different hyperlink designs in T-IMM OO affected students' performance and the dynamic-hyperlink version was most effective for learning. To further investigate learning effects of the three hyperlink versions more closely, how many students attempted to answer each sub-task and their performance with it were examined. The results are summarised in Table 6-8.

As for test 1 results, students in the no-hyperlink group made the least attempts to answer the sub-task 2 and the sub-task 3, and the mean was much lower than the other two groups. Even for the sub-task 1, the performance of this group was lower. More students in the static-hyperlink group made attempts to answer the sub-task 2 than the dynamic-hyperlink group, and similar percentage of students between the static-hyperlink group and the dynamic-hyperlink group tried the sub-task 3. This result may suggest the static hyperlink version was beneficial for students to grasp knowledge quickly. However, as the mean marks of each question indicate, the solutions from students in the dynamic-hyperlink group were more accurate than the other two groups.

Variations of T-IMM OO	Test 1						
	Attempts made (%)			Students' marks for each question			
	T1	T2	T3	T1(50%)	T2(20%)	T3(30%)	Total
No-hyperlink group (%)	100	50	22	25.8	6.6	4	36.4
Static-hyperlink group (%)	100	88	60	26.4	10.4	6.8	44.0
Dynamic-hyperlink group (%)	100	69	63	31.4	9.8	12.8	55.2
	Test 2						
	T1	T2	T3	T1	T2	T3	Total
No-hyperlink group (%)	100	100	63	36.8	13.6	13.6	64.2
Static-hyperlink group (%)	100	82	71	34.2	12.4	14.0	59.8
Dynamic-hyperlink group (%)	100	100	100	37.0	14.4	22.0	74.8
T1: sub-task 1 (creating a class diagram), T2: sub-task 2 (producing a collaboration diagram), and T3: sub-task 3 (about producing collaboration diagrams with the execution patterns)							

Table 6-8 Students' attempts made to tasks in test 1 and test 2, the mean marks of each question

As for test 2 results, the no-hyperlink group performed better for the sub-task 1 and sub-task 2 than the static-hyperlink group. Although their attempts to the sub-task 3 were still lower than the static-hyperlink group, their overall performance was better. Possible reasons identified for this result will be discussed in next section. In terms of the dynamic-hyperlink group, 100% of students attempted all three tasks and their performance for each question was higher than the other two groups. The analysis of students' solutions to the tasks in the two tests suggests that this group had clearer understanding of object-oriented concepts and could apply them more accurately in designing with UML. The results presented so far indicate that the dynamic-hyperlink version of T-IMM supported students' learning with the subject matter most effectively. This indicates that learning was more effectively supported with providing hyperlinks for students to directly access related information in R-IMM OO when they answered incorrectly or after they did design tasks than providing hyperlinks together with questions.

The result from test 1 and observations into students' use of IMM OO raised a question: 'How much did the students in the no-hyperlink group search related information in R-IMM or any other learning materials?' During observations in tutorials it was noticed that advanced students used a combination of learning materials at the same time. For example, they used the paper-based SD 1B booklet and other online-resources together and when they needed, they asked questions to their tutors. They often did a couple of works, i.e. programming and learning object-oriented concepts, at the same time, switching between them.

Not surprisingly, weak students seemed to use one type of learning material and to do one work at one time. As a result, they were more likely to be affected by what types of learning materials, in this study IMM OO, they used and how much learning supports the materials and their tutors. Analysis of the tests results and observations in tutorials brought two possible problems with weak students' learning with programming subjects. One is that if finding related information requires an effort, students may try to memorise the model answers without trying to find out why their solutions are different and trying to correct their misconceptions. The other is that students may not know what information to look for and where to look. For both problems, learning supports either from tutors or IMM courseware with hyperlinks can help students construct their knowledge.

In addition, during the analysis of students' performance between the three groups, a question was raised: 'why the performance of the static-hyperlink group did not improve even as much as the no-hyperlink group? The reasons identified will be discussed in next section. Prior to this the learning effects of hyperlinks in T-IMM OO identified from analysing data from 2 questionnaires and interviews, tracking files and students' interactions with IMM OO observed during tutorials.

Students' use of hyperlinks in T-IMM OO in tutorials and the learning effects

Between three hyperlinks groups, the static-hyperlink and the dynamic-hyperlink groups performed significantly better than the no-hyperlink group. One main reason identified from tracking data was the frequency of students' revisiting related information in R-IMM. Even though students could access information easily with 'search', 'glossary' or 'menu', not many students visited R-IMM OO before or after they answered questions in T-IMM OO. When they answered incorrectly or did a design task, some students asked questions to their tutor or peer students. However, others moved to the next question. Often it was not because they came to understand why their answers were incorrect and corrected their misconceptions.

From the observations in tutorials it was noted that some students checked the model answers first, came back to the question and revised their answers carefully. They did not put the exact copy of the model answer. But they seemed to try to 'assimilate' their own answers based on the model answers given. These students did not seek information in either R-IMM OO or the module booklet although various means were available to find the related information. As a result, the frequency of their revisiting information in R-IMM OO from the questions or tasks in T-IMM OO was less than either the static-hyperlink group or the dynamic-hyperlink group.

An interesting thing was that only the tutor in this group asked students to learn with R-IMM OO first and then to do the tasks in T-IMM OO. As students used R-IMM OO for learning, the frequency of encountering information in R-IMM could not be the main reason for the difference in students' performance between the three groups. The difference seemed to be related to how often students accessed the information in R-IMM OO when they needed it either to answer questions or to find out why their answers were incorrect.

To investigate why students' performance differed between the static-hyperlink group, and the dynamic-hyperlink group, their interactions with IMM OO from tracking data and observations were analysed. Once students became aware that they could directly access related information in R-IMM OO, they used them frequently (both static and dynamic). Few students required help to use this feature. To determine whether the frequency of students' using hyperlinks in T-IMM OO also affected students' performance between the static-hyperlink and the dynamic-hyperlink groups, students' records from tracking files were compared. Tracking data showed that there was no significant difference between the number of times the static-hyperlink and the dynamic-hyperlink groups used hyperlinks from each tutorial unit in T-IMM OO. The static-hyperlink group used them slightly more frequently than the dynamic-hyperlink group. But it was expected because in some tutorial units with multiple choice questions or fill-in types, the dynamic-hyperlink group had hyperlinks only after they answered incorrectly. This result suggests that learning effects from the dynamic-hyperlink version was contributed by more than the number of times students encountered related information.

The data from the pilot study, reported in the previous chapter, showed that students with the dynamic-hyperlink version had stayed in R-IMM OO longer when they visited it from T-IMM OO. To determine whether the duration of time students stayed in R-IMM OO when accessed directly from questions and tasks in T-IMM, tracking and observations data were reanalysed. When students visited R-IMM OO with hyperlinks from T-IMM OO, both the static-hyperlink and dynamic-hyperlink groups accessed other content pages in R-IMM. A difference between the two groups was that the dynamic-hyperlink version seemed to pay more attention to and spent more time on the information presented in R-IMM OO than the static-hyperlink group. The static-hyperlink group stayed shorter and tended to click through the content pages quicker.

These students' interactions with IMM OO point two possibilities: the static-hyperlink group was looking for related information to articulate their answers, and the dynamic-hyperlink group was more careful in reading because they realised their misconceptions or their inadequate understanding to solve the task they were doing.

In the tutorial 7 in T-IMM OO, hyperlinks were embedded neither for the static-hyperlink nor the dynamic-hyperlink version (Tutorial 7 in T-IMM OO contained multiple choice questions). It was deliberate to observe students' reactions. During an observation, a student with the dynamic-hyperlink version showed much frustration when no hyperlink appeared even though she answered the question incorrectly. She repeatedly clicked other choices, making frustrating sounds. When she was explained that there was on hyperlinks provided for the question, she expressed her frustration of not having them but did not try to find relevant information in R-IMM OO by herself. During an interview after the tutorial, she citied that not being able to access related information directly unlike in previous tutorials in T-IMM OO was dissatisfactory. The results in terms of students' performance and their interactions with IMM OO have so far suggested that providing hyperlinks as part of feedback for students to clarify students' understanding supports student learning most effectively.

Students' revisits to the related information that was already taught in lectures *after* realising their misconceptions probably provided a clearer focus on what they were looking for. This focus may have promoted students' reflection and recall of what was delivered during the lectures and how they were explained. As a result, accessing the related information in R-IMM OO and reflecting on the teaching in lectures with R-IMM OO probably helped students clarify and correct their misconceptions. This may have then helped the students conceptualise other object-oriented concepts and design taught in the following lecture better than other groups because their knowledge constructed was clearer. The cognitive effects supported by the dynamic-hyperlink version of T-IMM OO in actual learning and teaching contexts were further investigated in case studies 2 and 3, which will be reported in Chapter 7 and Chapter 8.

Students' preferences of hyperlinks

In week 13 students' preferences of hyperlinks in T-IMM OO were questioned. As illustrated in Figure 6-5, 69% of students (11/16) preferred dynamic hyperlinks and 25% (4/16) static hyperlinks. Five students from the no-hyperlink group chose dynamic hyperlink as their preferred type. These responses were probably affected by students' satisfaction with hyperlinks in T-IMM OO they had (the static & the dynamic-hyperlink groups), and by their considerations.

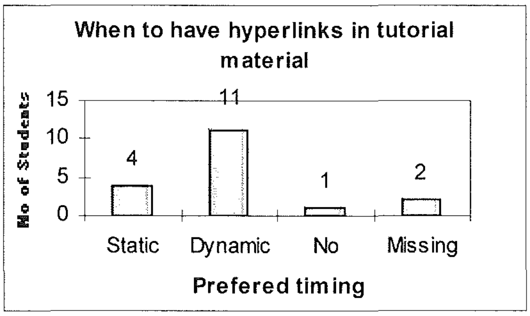


Figure 6-5 Students' preference of hyperlinks in T-IMM OO

In addition, the dynamic-hyperlink group responded to the usability assessment questions about 'hyperlinks helping their understanding of OO concepts' and about 'hyperlinks useful for problems solving' most positively. All in the dynamic-hyperlink group agreed to the first question, but 3 students from the static-hyperlink group neither agreed nor disagreed. Also, four students from the no-hyperlink group neither agreed nor disagreed to the first question, and two students to the second question, which was not surprising as they did not use hyperlinks in T-IMM OO.

Advantage of the static-hyperlink version

During observations, one main advantage of the static hyperlink version was found. A particular student missed three weeks tutorials and lectures due to illness. Using IMM OO for independent learning the student could catch up with the module. However, in the beginning when she tried to answer questions in T-IMM OO, she found it difficult with the no-hyperlink version (she belonged to tutorial group A). It was considered that the static-hyperlink version could accommodate her learning needs most effectively because she neither had sufficient knowledge to test nor to find required information in R-IMM OO yet. *Lecturer N* recommended her to use it. After studying with IMM OO for two weeks, she achieved 42% from test 2. She did not take test 1 as she came to university in week 4 for the first time in the semester and had no knowledge of the subject matter. Considering her learning situation, she performed well in test 2. More importantly, she felt confident in her learning of the subject matter. During an interview, she emphasised that with IMM OO it was easy to understand the concepts and it helped her catch up her studies with the module.

It seems that when students are new or nearly new to certain topics, the static-hyperlink version of T-IMM OO can be more suitable because it can help students access related information directly. This does not require much cognitive effort in acquiring the related information, but at the same time it helps students to conceptualise and construct knowledge. This may explain the students' performance from test 1 (see Table 6-8), in which more students in the static hyperlink group attempted to answer the sub-task 2 although their performance of the question was lower than the dynamic-hyperlink group.

6.5.3 Students' performance affected by the use of IMM OO in tutorials

As reported in Section 6.5.2, students' performance from test 1 and test 2 differed significantly depending on the variations of T-IMM OO used. From both of the test results the dynamic-hyperlink version of T-IMM OO was found to be most effective in supporting student learning in the learning context. In addition to the students' performance being affected by their use of the three different variations of T-IMM OO, a difference in students' performance was found between tutorial groups that used the same version of T-IMM OO. This revealed that there were other factors which affected students' learning with IMM OO. To investigate what affected students' performance between the tutorial groups, test 1 and test 2 results were further analysed together with other data. The results of test 1 and test 2 are summarised in Table 6-9.

Tutorial group	**A**	**B**	**D**	**E**	**C**	Total
T-IMM OO used	**No-hyperlink**	**Dynamic-hyperlink**		**Static-hyperlink**		
Mean of test 1 (%)	40.4	57.8	66.0	**50.4**	**49.5**	45.2
Mean of test 2 (%)	71.3	86.0	83.1	**69.8**	**55.1**	66.3
Improvement	**30.9**	**28**	**17**	**19**	**6**	21.1

Table 6-9 Students' performance between tutorial groups and with three variations of T-IMM OO

There are three interesting results to note: students' performance between their use of the three different variations of T-IMM OO, students' performance between Group C and E, and the differences of the performance improved between 5 tutorial groups. How the three variations of T-IMM OO affected students' performance was already reported in Section 6.5.2. What variables affected the second and third will be reported in this section.

Students' performance between Group C and E: using T-IMM OO vs. not using it in tutorials

Both tutorial group C and E used the static-hyperlink version of T-IMM OO. Test 1 and test 2 results of tutorial group C and E are illustrated in Figure 6-6.

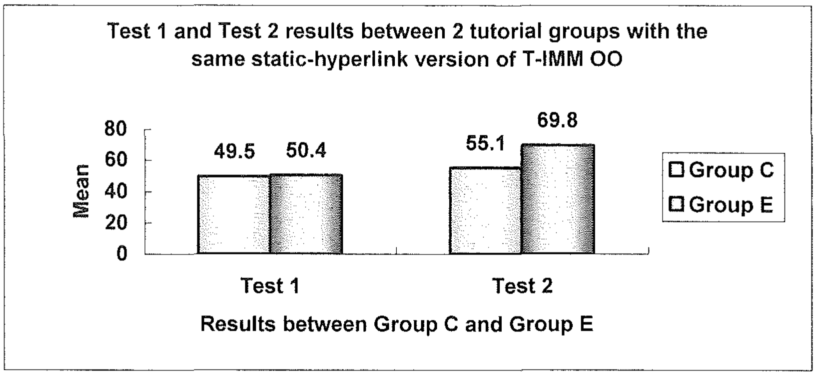


Figure 6-6 Improvement of Group C and Group E's performance between test 1 and test 2

From test 1 both tutorial groups obtained similar results, but in test 2 the performance of Group C improved much less than Group E. Possible reasons were explored from examining the learning contexts. As the academic performance of Group C from SD 1A in their previous semester was better than Group E, the possibility that this result was influenced by their background knowledge was excluded. Analysis into students' learning in Group C enlightened two variables which could be associated to this result: the difference in Group C and E's use of IMM-OO in tutorials; and the change of teaching staff in Group C.

As described in Section 6.3.3, the tutor originally assigned to Group C could not come to work due to his illnesses. For the first two weeks, *Lecturer N* assisted Group C tutorials, and from week 4 the demonstrator of the group took charge of the tutorial group as their tutor. He was not aware that T-IMM OO was part of the tutorial materials for the first 5 weeks and for one hour of each tutorial students were expected to do tasks in it. (When T-IMM-OO was introduced to students in week 2, the new tutor, a demonstrator at the time, was at present; however, he considered T-IMM OO for the tutorial only.) Instead of asking students to do tasks in T-IMM OO for an hour in tutorials, he helped students to learn how to use the modelling tool, ROME, and asked them to do the programming tasks which were continuously used from the previous semester. As a result, students in Group C did not use T-IMM OO in week 4 and 5.

Tracking files revealed that only a few students continued to use T-IMM OO. Unfortunately, observations in Group C were discontinued because the timetable of this group was overlapped with Group D and needed to oversee test 1. It was week 5 when we realised that Group C did not use T-IMM OO.

As already mentioned, students in Group C performed better in SD 1A module, which excludes their background knowledge affecting the test 2 results of Group C and E. They both had the same lectures and same learning materials. Moreover, they performed similarly in test 1 as a result of using the same static-hyperlink version of T-IMM OO. As reported in Section 6.5.1, a significant difference was found in students' academic performance of the module between the students who used IMM OO for learning and who did not. These factors suggest that the difference between the performance of test 2 between Group C and Group E could be contributed by Group C's not using T-IMM OO in week 4 and week 5 tutorials. When test 1 was performed, their performance did not show a significant difference. However, before test 2 Group C did not use T-IMM OO for two weeks and Group E continued to use it for learning in tutorials. The result was that whereas the performance of Group C did not improve much, the performance of Group E improved as much as other tutorial groups.

This suggests an importance of facilitating both teaching and learning with IMM courseware to support the learning process. If students revise after lectures and do some practical tasks to test their understanding actively, using task-oriented materials like T-IMM OO in tutorials may not be needed. Not many students revise what they learnt in lectures first and then apply them in the practical tasks. When students did practical programming tasks, coursework or lab-session tasks, they showed a tendency to start programming first rather than to test their understanding of underlying concepts and principles. With T-IMM OO in tutorials, students were able to test and construct their understanding of OO concepts first. Then, they could apply them in actual design and programming tasks.

The result discussed points out two things. One is the importance of supporting the 'iterative' process of learning and teaching. The other is there is a need to facilitate students to obtain a good understanding of programming concepts before applying them in design and implementation of programming. In addition, this result illustrates the effectiveness of the integration of IMM OO in lectures and tutorials in facilitating student learning.

6.5.4 Active versus passive teaching affecting student performance with IMM OO

How much students' performance improved between test 1 and test 2 seemed different between tutorial groups (see Table 6-9). The improvement of students' performance between 5 tutorial groups is illustrated in Figure 6-7.

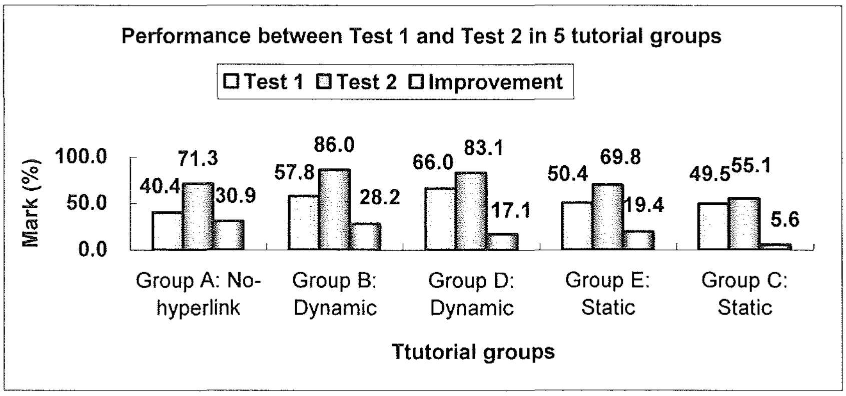


Figure 6-7 Students' performance improved between test 1 and test 2

The performance between Group A and Group B improved more than the other groups. Group D and E improved similarly, and Group C improved the least. As discussed above, the difference between Group C and E was caused because Group C did not use T-IMM OO in week 4 and 5. As for Group B and Group D, both groups used the dynamic-hyperlink version of T-IMM OO, but how much their performance improved between the two tests differed. It was interesting to investigate what affected students' performance between Group B and D particularly when Group B had part-time and elective students and the part-time students could not attend Friday lectures.

There could be several variables that influenced the difference in the improvement of students' performance between 5 groups. Analysis of interviews and observations data revealed differences between Group D and Group E tutors, and Group A and Group B tutors. Differences lied in their perceptions of teaching and learning programming, their attitudes to IMM OO in the learning context, and their approaches to teaching as well as their preparation and understanding of the learning context. The differences can be perhaps described as 'active teaching' vs. 'passive teaching'.

Active teaching: tutors' supports and attitudes in Group A and Group B

Both tutors of the tutorial groups, *Lecturer N* and Tutor B, were involved in the development of IMM OO, and as a result they were aware how it was integrated and used in the curriculum. However, this was not the main difference between Group A and B, and Group D and E. The main difference was their learning supports and attitudes in tutorials.

During tutorials, *Lecturer N* and Tutor B came to each student and *asked* them how they were doing and if they needed any help or had any questions. Also, both tutors encouraged students to use T-IMM OO together with the booklet for learning in tutorials. *Lecturer N* encouraged students to use R-IMM OO first and then T-IMM OO; he was the only member of the teaching staff who asked students to use R-IMM OO. As for Tutor B, he was concerned about the part-time students' missing Friday lectures due to their work schedule and arranged for them to get a copy of IMM OO for home use. Any one could make their own copy of IMM OO for home use, and some students did by themselves.

In week 4 and 5, when students started design tasks in T-IMM OO, both lecturers demonstrated how to use the modelling environment, ROME. They helped students to be actively involved in the design tasks. In addition, they encouraged students to do the programming tasks after doing tasks in T-IMM OO.

Passive teaching: tutors' supports and attitudes in Group D and Group E

From interviews with Tutor D and Tutor E, it was discovered that they were unaware of IMM OO until they came to the first tutorial. Initially, this affected their approaches to teaching in tutorials. For example, in the first tutorial Tutor E asked the author to answer students' questions although the questions were about the subject matter.

In the previous semester paper-based programming tasks were used for the SD 1A module (Java programming), and they thought the materials were going to be used for the SD 1B module as well without any change. In fact, they were continuously used for programming tasks in addition to T-IMM OO. Until the interviews, both tutors were unaware that R-IMM OO was integrated for lectures and T-IMM was associated with the material.

However, a fundamental difference found between Tutor D and E, and Tutor A and B was, as mentioned above, about how they approached teaching. Unlike *Lecturer N* and Tutor B, both tutors *waited* for students to ask questions or help. Furthermore, both did not consider IMM courseware was suitable for tutorials.

> *TE*: It's a very useful tool for reference and for going over things again *outside* of lectures and tutorials and the students can work their own pace. The disadvantage is that students tend to use it too quickly and not think very much for themselves as they know they can get an immediate answer to each question. Also, they do not think the teacher is involved at all so *they don't ask questions. This is a matter of educating the students.* ...Disadvantages are that the teacher becomes too distant from the student learning process.

Excerpt 6-1 Tutor E's view on IMM: suitable for learning outside of lectures and tutorials

Whereas Tutor E considered IMM OO had its place for independent learning, Tutor D had a negative view to IMM-based learning. He cited that in tutorials students needed to be actively involved in programming tasks with their tutors, and IMM OO prevented the students from doing the programming work. When he was further questioned, it was found that he had never visited IMM OO and did not know what it contained. Nor had he considered students would need help when they learnt with IMM courseware. In week 6, he blamed using IMM OO in tutorials was responsible for the students' attendance drop in the group. When the students' attendance records, kept by the author, were checked between week 1 and week 6, the only group in which students' attendance rate dropped significantly was Group D.

One interesting thing was that both tutors perceived that in order for IMM courseware to support student learning, it needed to respond students' actions.

> *TE*: I think it has its place as an addition to 'normal' teaching methods – I think its biggest use could be in providing feedback in some way to students but this may be something for the far future! As reference material and means of going over examples it is very useful.

Excerpt 6-2 Tutor E's view on the role IMM for learning

As expected, in week 4 and 5 both tutors neither demonstrated how to use ROME nor encouraged students to do design tasks in T-IMM OO with it. They helped students when the students asked questions. The differences in attitudes and learning supports between the two groups of tutors seemed to have affected students' learning experienced as well as their performance. Perhaps, promoting interactions between students and tutors with IMM in tutorials is '*a matter of educating the teaching staff*' as opposed to Tutor E's comment about 'it's a matter of educating the students'.

6.6 Results: student learning experience with IMM OO - perceptions

Learning effects of IMM OO in the learning and teaching context for students' performance were reported in Section 6.5. Students' motivations to learn and their interests in the subject matter they are studying affect what and how they learn. Their perceptions of learning contexts also influence their approaches to learning and their learning outcomes. More and more lecturers in higher education aim to facilitate teaching and learning in a way to promote students' intrinsic motivation of 'wanting to learn' and their interests in what they are studying through creating a learning environment in which students perceive it affords a 'deep' learning approach (Race, 1998). This section will report how students perceived their learning with IMM OO integrated for teaching and learning: their perceptions of the subject matter they were studying, their self-reported enjoyment of the module compared with others, how much IMM OO in the context helped their learning and their preference of teaching and learning methods.

6.6.1 Student perceptions of learning with IMM OO

At the end of week 2 and week 13, questionnaire surveys were conducted to ascertain how students experienced their learning with IMM OO in the educational context. Figure 6-8 illustrates students' self-reported perceptions of object-oriented design.

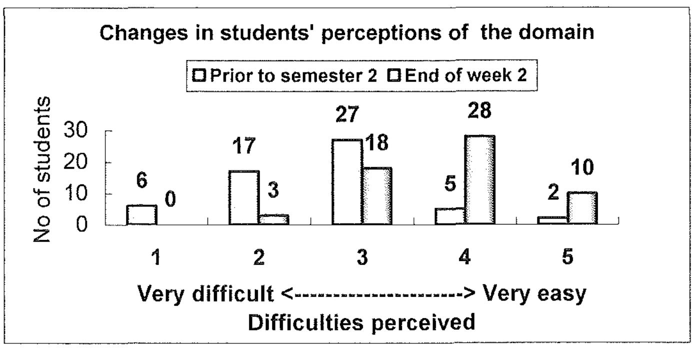


Figure 6-8 Students' self-reported difficulties of the subject matter

As displayed in Figure 6-8, there was a positive change in students' perceptions of the subject matter. Only 5% (3/59) rated it difficult whereas 39% (23/59) had perceived it difficult prior to the semester. Particularly 64% (38/59) students considered the subject matter easy. As most did not have a prior experience of studying object-oriented paradigm, one may consider students' actual learning of the subject matter changed their perceptions of it more positively. However, students studied Java programming, and their perceptions of object-oriented design could be formed based on their experience with it as well as other programming modules in the previous semester. To determine if students' perceptions of the subject matter changed, they were asked again at the end of week 13. Much less students responded to this questionnaire as it was performed at the end of semester 2, and students were busy doing their coursework. The result is illustrated in Figure 6-9.

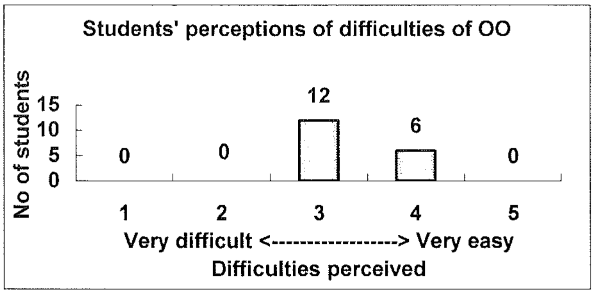


Figure 6-9 Students' perceptions of the module at the end of week 13

None of the students rated the subject matter difficult, but the percentage of students who considered it easy reduced from 64% (38/59) to 33% (6/18). As this question included 'Java programming' as well as 'OO design', the students' responses may be affected by their perceptions of 'Java programming'. However, their overall perceptions are quite positive.

From week 1, R-IMM OO was used in lectures, and students used T-IMM OO for learning in tutorials. A question is how much did the integration of IMM OO contribute to students' perceptions of the subject matter? To answer this question, students' perceptions this year were compared with the previous year students; the data was collected from the preliminary study, which was reported in Chapter 3. The previous year students had Toolbooks in lectures and for independent learning instead of IMM OO in lectures *and* tutorials. As for other learning materials and design tools, both used the same ones.

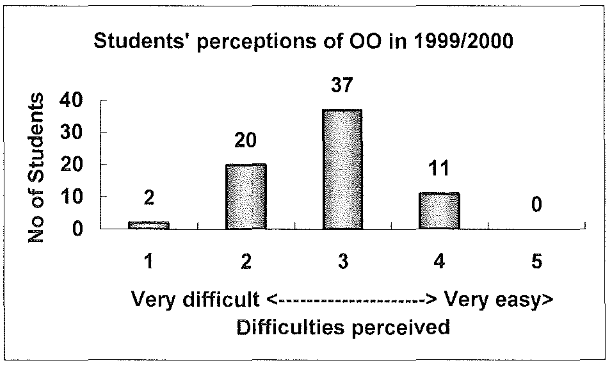


Figure 6-10 Previous year students' perceptions of the subject matter 1999/2000

In the previous year, 31% (22/70) students rated the subject matter difficult, and only 16% considered it easy. Students' perceptions in 2000/2001 were more positive both at the end of week 2 and week 13. In addition, students' perceptions of OO subject matter at Brunel University were examined to determine whether this subject matter was perceived difficult or easy. The data from the pilot study, reported in Chapter 3, revealed that much less students (5%) perceived the subject matter easy, and at the same time more students rated it difficult (42%). When compared the results from students' responses in the previous year and at Brunel University, students' perceptions with IMM OO in this study were much more positive.

Students' positive perceptions of the subject matter could be contributed by the integration of IMM OO in lectures and tutorials. However, this does not answer how much it affected students' perceptions. Data was further analysed to investigate students' learning experienced with IMM OO in the learning and teaching context.

6.6.2 Active learning with IMM versus passive learning with paper-based tasks

Students' interactions with IMM OO in tutorials

This section will describe students' interactions with IMM OO in tutorials, their interactions with their peers and tutors, and their use of other learning materials or tools. Observations in tutorials were conducted for tutorial group A, B, E from week 2 to week 6. However, all 5 groups were observed in the first week and in the weeks when the two tests were performed.

Students' interactions with IMM OO

Most students, excluding a couple of students leaving for medical reasons, finished tasks in IMM OO. Generally, few asked questions about how to use IMM OO. Students seemed to be much involved in their learning with IMM OO. Also, seemed to enjoy the experience, which was reflected on their positive responses to the usability assessment questions in week 13 (Table 6-10). Some students made "thumb's up" sign or nodding when they got correct answers. Some said "Aha!" or laughed when they checked the model answer after answering a question incorrectly.

Active learning with IMM OO

Two most cited benefits, offered from IMM OO in the learning and teaching, were 'interactive learning' and 'control of learning' it supported. Students' interactions with IMM OO in tutorials observed and tracking data revealed how students experienced their learning of object-oriented design with IMM OO. R-IMM OO contained resources for object-oriented analysis and design with UML (class diagram and collaboration diagram only), and T-IMM OO consisted questions for object-oriented concepts and design tasks with UML.

From tutorial unit 5, students started design tasks in T-IMM OO using ROME. They ran ROME from T-IMM OO and could switch between two applications. In T-IMM OO, with design tasks were provided for students to access related information. The hyperlinks were not only for the related design method but they included links to underlying object-oriented concepts required for the design task. During tutorials, students repeatedly returned to earlier tutorial units in T-IMM OO which they did in week 2 or week 3. It seemed that when students were doing design tasks in T-IMM OO, they often used R-IMM OO.

Repeated use of IMM OO

At the beginning of each tutorial, particularly with Group A, students were asked to use only a certain amount of T-IMM OO. Initially some tried to go through all at once but most went through as suggested. It was noted from observations and tracking files that students did the same tasks in T-IMM OO or visited same content in R-IMM OO repeatedly until they were satisfied. Students concentrated to answer questions correctly, particularly open questions. Some corrected their own answers after comparing theirs with the model answers. Some put any character to access the model answer because without answering the question, they could not access the model answer.

But they did not copy the model answer. They got back to the question and put their own answer. The reason seemed either these students were disinclined to try to put their own answers first in case they made incorrect answers or they wanted to get a hint before putting their own. These students were often observed to return to questions again later. With multiple choice questions students repeated them until they got all the questions correct. Students showed much disfavour when open questions or the answers were not clear enough or did not meet their expectations even though their tutors could clarify them. It was one that students cited that they liked the least and asked for improvements.

Control of learning

Tutor D and E mentioned during interviews that students' learning, especially 1st and 2nd year ones, should be controlled by tutors. But students' learning with IMM OO suggested that they could take some control of their learning with given supports. For the first two tutorials, most students left labs after they finished the tasks in T-IMM OO although they were asked to do paper-based programming tasks. Tutor D and E viewed IMM OO in tutorials responsible, asserting that learning with IMM OO led students to leave the tutorials believing they learnt everything from it.

However, observations and interviews with students suggested that Tutor D and E's assumption was very unlikely. A main reason seemed that the paper-based tasks did not offer any guidance students could easily get whereas IMM OO did. When *Lecturer N* and Tutor B encouraged students to start the programming tasks from week 4 and showed them how to do them with ROME and Java compiler, the students in these groups gradually began to do programming tasks.

Active interaction between peer students, and between students and tutors

While using IMM OO, active interactions between peer students were observed. Students discussed their solutions with each other, particularly in Group A and B.

Tutor D and E considered that using IMM OO during tutorials led students to think tutors were not involved in their learning process, and as a result, students did not ask questions to their tutors often. In fact, students' questions were reduced. But unlike the tutors' assumptions, it was primarily because students could assimilate their own solutions with IMM OO. In terms of interactions betweens students and tutors, using IMM OO seemed to support their interactions in some tutorials. As for tutorial group A and B, active interactions between students and tutors were noted, and some were initiated by tutors and the others were by students. In particular, the tutor of the tutorial Group C cited that one of advantages of having IMM OO in tutorials was that he could provide more supports to students.

Flexible use of IMM OO

One of the key advantages of IMM courseware is that it can be used at one's own pace and in their own time. It was observed and found from tracking files that students did use IMM OO on their own pace as well as in their own time. Students spent as long as they wanted on a task in T-IMM OO or a content page in R-IMM OO. Students played animations as many times as they wanted. In terms of using it in their own time, tracking data found in computer labs indicated students' independent use of it. In addition, students used IMM OO well together with other materials and software. They used the module booklet or other books when they needed further information.

Question types: most beneficial and most liked

As presented in Figure 6-11, 50% regarded open questions with a task (mostly design tasks using ROME) most beneficial, and 30% (5) considered filling-in questions. These question types were what required students' active involvement in solving the tasks.

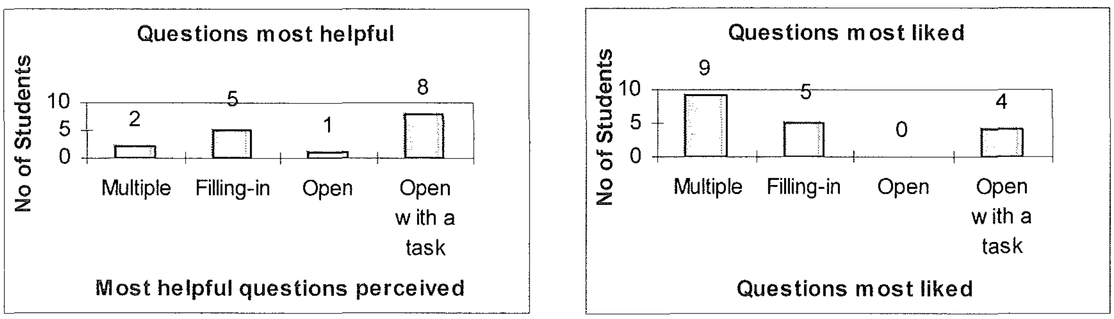
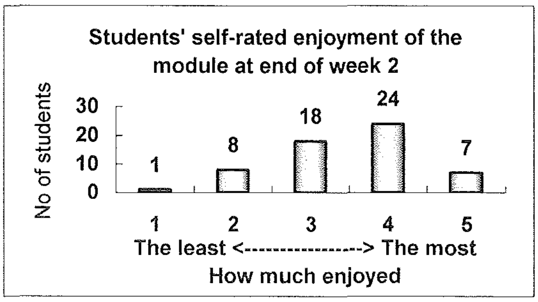


Figure 6-11 Questions most beneficial and most liked

What was liked most were multiple choice questions (53%), and next filling-in (29%) and open questions with a task (24%). One thing to be noted is that not only did no one liked open questions but only one student considered the type most beneficial. This could be partly explained by students' comments about ambiguity of some answers of open questions that made them unsure if their answers were correct.

Students' self-reported enjoyment of studying OO subject

Students were questioned in both questionnaires about how much they enjoyed studying the module compared with others. The results are illustrated in Figure 6-12.



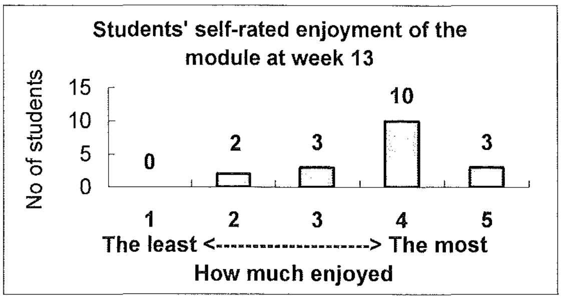


Figure 6-12 Students' self-rated enjoyment of the module compared with others (left: at the end of week 2, and right: at the end of week 13)

At the end of week 2, 53% of students (31/59) responded that they enjoyed the module more than others. Only 15% students (9/59) rated their enjoyment of the module less than other modules. At the end of week 13, 72% of students (13/18) responded that they enjoyed the module more than others. When students' responses from two questionnaires were compared, most students who reported their enjoyment high at the end of week 2 responded positively at the end of week 13. The one student who responded 'the least' at the end of week 2 was one who did not consider using IMM OO could improve his/her understanding with object-oriented subject.

To determine what factors affected students' enjoyment of studying the module, their responses from the questionnaires were analysed together. It seemed that the students' prior experiences with multimedia and their preferences of teaching and learning methods were related to how much they enjoyed the module both at the end week 2 and week 13. The majority preferred to have IMM courseware for both teaching and learning, and their preferred methods of learning at week 13 were using both IMM and paper-based materials together. These responses indicated how beneficial they considered the integration of IMM OO for both teaching and learning. At the same time they suggest that the integration of IMM OO affected their enjoyment of studying the module.

Students' responses to their preference for teaching methods at the end of week 13 brought some useful insights to understand students' learning experienced. Half of the students (9/18) cited that they preferred traditional teaching methods and the other half multimedia. The intention was not to evaluate IMM OO vs. *Lecturer N*'s teaching; but some responses indicated that comparison was made and influenced students' responses. They considered IMM OO in the learning context helpful, but they were well aware that it was only a learning aid. The students seemed to perceive teaching as whole and valued the quality of teaching. The following is a comment students made:

> *N01S1:* I have not marked the IMM materials particularly highly. *This is not because I did not like the material, but because it was being compared to the teachings of [Lecturer N].* As I find his teachings very easy to learn from, any addition teaching aids pale into insignificance.

Excerpt 6-3 A student's comment on how much valued good teaching

It was important to note that the students who preferred teaching method with multimedia graded their enjoyment of the module much higher than the others; 89% of them (8/9) cited they enjoyed the module the most. It was also reflected how much they considered IMM helped their understanding of OO design concepts.

To determine how much students' using IMM OO for teaching and learning affected their perceptions (either negatively or positively), their responses from the usability assessment questions, part of questionnaire 2, at the end of week 13 were examined. Questions and students' responses concerning their perceptions of IMM OO in the learning and context are summarised in Table 6-10.

	Questions	SA	A	N	D	SD	M
A	I enjoyed using the IMM materials *for lectures*		36	50	14		
B	I enjoyed using the IMM materials *for tutorials*		57	43			
C	I enjoyed using the IMM *lecture* materials for independent learning	14	21	64			
D	I enjoyed using the IMM *tutorial* materials for independent learning	14	36	50			
E	The IMM *lecture* materials were beneficial for my understanding of OO concepts	22	50	14	14		
F	The IMM *tutorial* materials were beneficial for my understanding of OO	21	57	14	7		
G	I would like to use more IMM learning applications like this for *lectures*	14	29	29	21		7
H	I would like to use more IMM learning applications like this for *tutorials*	29	36	29	7		
I	I would like to use more IMM learning applications like this for *independent learning*	7	50	29	14		
J	I have used/will use the IMM materials when revising	7	50	36			7
K	I felt in control of my learning at all times	14	43	36	7		
N	I now have good understanding of OO concepts		71	29			

Where A = agree, SA = strongly agree, N = neither agree or disagree, D = disagree, SD = strongly disagree
All figures are percentages
Not all rows add up to 100 due to rounding effects

Table 6-10 Summary of students' responses to the usability assessment questions at week 13 (n = 14)

For the usability questions between R-IMM OO and T-IMM OO, students' responses were more positive with T-IMM (B, D, F and H), which can be indicative of their inclination for active involvement in their learning.

Help from IMM courseware

At the end of week 2, 93% of students (55/59) responded that IMM OO for teaching and learning *could improve* their understanding with OO subject. When students were asked again at the end of week 13, 89% (16/18) responded that IMM OO *helped* them understand OO concepts with Java programming. To the question about 'how much IMM OO helped their learning with the subject matter', 56% of students (10/18) considered it helped their understanding greatly as illustrated in Figure 6-13.

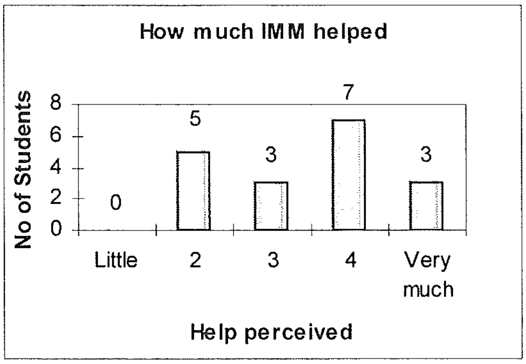


Figure 6-13 Help from IMM OO

It was interesting to find that the 5 students who rated IMM OO help to 2 had very high marks from SD 1A module. The mean was 92.6, which was higher than the mean of the module. As the amount of information IMM OO contained was not much, it was not surprising.

6.6.3 Benefits and weaknesses of IMM OO in the learning context

Data from open-ended questions in two questionnaires and interviews were categorised to explore what benefits and weaknesses students perceived to have from the design and integration of IMM OO in the learning context.

A. Benefits and strengths identified

Benefits and strengths students identified can be divided in two areas: one by the integration of IMM OO for teaching and learning, and the other the architecture and design features of IMM OO itself.

1) Benefits from supporting teaching and learning processes

Supporting teaching in lectures

Students cited that visualisation during lectures enhanced and clarified the lecturer's explanation. These eased their understanding of object-oriented concepts and design.

Learning with IMM OO after lectures

Second benefit students cited was reuse of IMM OO after lectures. When they were using it after lectures, they could recall the lecturer's explanation given verbally. It also corrected or enhanced their understanding gained from lectures

Interactive learning (7 students)

The essence of multimedia-based learning is interactive learning. Some students identified this as a key strength of IMM OO in the learning context. They described that learning with IMM OO was more active, and it made them think more and encouraged them to be involved in their learning more. This was because that they used T-IMM OO in tutorials and for learning.

Control of learning (8 students)

Eight students mentioned this as one of the main strengths IMM OO offered.

2) Benefits from the design of IMM OO

What students found helpful from the design of IMM OO were direct access to information, visualisation, content structure and information representation.

Easy information access

Students cited that it was easy to find information with IMM OO; all students agreed to the usability questions about "easy to use" and "easy to find information" in the questionnaire 2. During an interview, a tutor commented that students used IMM OO even after they stopped being used as tutorial materials to look up some information. The tutor informed that students normally do not look up handouts or books often.

Hyperlink support

Learning effects of hyperlinks in problem-solving contexts were already discussed in Section 6.5.2. Students considered hyperlinks as a part of feedback and considered them very helpful for their learning.

Visualisation

To the usability question about 'visualisation helping their understanding', 100% of students agreed. The majority of students, except few who liked text only, responded that visualisation helped their understanding. Learning support from visualisation came from two different directions: one helping understanding during independent learning with IMM OO, and the other assisting teaching during lectures. As for the first benefit, students explained that visualisation, presented with text information, clarified or enhanced the meaning of text information. Also, they cited that breaking down complex concepts into easy and simple steps eased their understanding the concepts.

Observations and tracking data revealed that students played same animations repeatedly. Students considered the continuity of using similar real life objects helpful to follow the flow of the module. However, it also caused a slight confusion; some animations were similar, and they sometimes led students to think they were the same or sometimes they got bored to play them.

Content structure and information representation

The content structure was perceived as being clear and simple to conceptualise concepts and to build up understanding of them. And the amount of information presented on each page, and the information representation with mainly animation and its accompanying text were considered helpful. However, some students wanted to have more detailed information.

B. Weaknesses of the design and integration of IMM OO in the context

In addition to the benefits students identified, students mentioned some weaknesses from IMM OO in the context, which were:

- Not enough information in IMM OO to accommodate students when their knowledge became expanded;
- Not enough tasks in T-IMM OO to support different levels of students;
- Some animations were similar: they confused the students;
- Technical problems caused by computers;
- Inaccessibility without a computer unlike paper-based materials;
- Reading on a screen.

6.6.4 Factors affecting learning and teaching processes with IMM OO

Learning and teaching with IMM OO was affected by both teaching staff' and students' perceptions and attitudes.

Teaching staff or contexts affecting teaching and learning with IMM OO

How much teaching or teaching staff influenced students' learning with IMM OO was discussed in Section 6.5.4. Several factors were identified. Most are what affect teaching and learning processes with any learning materials, and they are: 1) teaching staff's conceptions of teaching and learning programming, 2) their perceptions of and attitudes towards IMM courseware in a classroom-based learning, 3) their learning support in the classroom, 4) communication between staff, 5) tutors' preparations prior to the semester. In addition, teaching staff's openness to a new method affected students' learning in the context.

Teaching staff's conceptions of teaching and learning programming

Some perceived that the 1st and 2nd year students' learning with programming needed to be controlled by tutors. Others tried to facilitate students' independent learning of programming. In terms of learning programming, some of the teaching staff cited that it is through hands-on experience of programming. The other seemed to focus on helping students grasp programming concepts first and then apply them in programming.

Teaching staff's perceptions of and attitudes towards IMM courseware

- <u>Positive view</u>

It freed a tutor from answering the same questions repeatedly as students could find their own answers from IMM OO. It helped the tutor focus on answering difficult questions while most found their own answers. It was perceived as an advantage because it was not always possible to answer all questions due to time constraints.

- <u>Negative view</u>

A tutor mentioned that IMM OO seemed to offer only simple navigation (never having actually tried it) and there was no cognitive difference between using multimedia and paper-based. He cited that tutorials were to be designed for activities rather than to use IMM courseware, which implied that IMM courseware, including IMM OO, did not offer activities. Also, it was cited that using IMM courseware during tutorials made a teacher become too distant from students.

Teaching staff's learning support in the classroom

Some tutors approached to support student learning actively, whereas others waited for the students to seek help from them.

Communication between teaching staff

As reported in Section 6.5.4, apart from the *Lecturer N* and Tutor B, who were involved in the development of IMM OO, the rest of the teaching staff only knew about IMM OO when they came to the first tutorial. Neither did *Lecturer N* inform the other teaching staff of what tutorial materials were going to be used nor did the other staff try to find out about it. Furthermore, they were unaware that R-IMM OO was used in lectures and T-IMM was associated with it. Even after they became aware of IMM OO, no teaching staff went through the material by themselves.

6.7 Summary

This study set out to investigate the learning effects of the design and integration approach, presented in chapter 4, and learning effects of hyperlinks. It also aimed to explore whether the use of IMM supported interactions in tutorials and encouraged active learning. Evidence from this study reveals that the use of IMM courseware in the context supported both students' performance and perceptions. In terms of hyperlinks, students with the dynamic-hyperlink version performed significantly better. From interviews and observations, contextual factors, in particular, how teaching affects student learning was explored. Based on these findings, the next case study aims to investigate individual student learning experience with IMM and to further explore personal and contextual factors that affect student learning with IMM.

CHAPTER 7 CASE STUDY 2: INDIVIDUAL LEARNING EXPERIENCE WITH IMM

This chapter reports a case study conducted at Brunel University in the second semester of 2000/2001 academic year. This is the second case study which was designed and implemented to investigate how effectively using IMM for both teaching and learning, the integration approach proposed in Chapter 4, facilitated student learning. As part of course materials, IMM courseware (IMM C++), described in Section 4.5.2, was developed by the author in collaboration with the module leader, *Lecturer B*, and integrated into the Programming and Software Development 2 module. This case study was designed based on the findings from the pilot study and case study 1, reported in Chapter 5 and Chapter 6.

Both case study 1 and this study investigated student learning with IMM to evaluate the effectiveness of the integration approach presented in Chapter 4. A difference between the studies is that whereas case study 1 focused on exploring students' learning experience with IMM as a group and this study focused on individual students' learning experience. The results from both studies were expected to enlighten the benefits of the integration approach for learning and to inform how to facilitate learning with IMM.

7.1 Research questions

This study aimed to answer the following research questions.

- How did individual students experience learning with IMM courseware used for both teaching and learning?
- Who benefited most from IMM C++ in the learning context?
- Did the use of IMM C++ in lectures and tutorials support students, particularly weak ones, to understand programming concepts?
- What were the benefits of using IMM courseware for both teaching and learning?
- What factors affected student learning with IMM courseware?

7.2 Methods

7.2.1 Participants

IMM C++ was integrated into the Programming & Software Design 2 (Pg & SD 2) as part of course materials. This module is one of the core modules for various Engineering and Computing courses, and 119 students registered the module in semester 2 of 2000/2001.

7.2.2 Programming & Software Design 2 module description

The Programming & Software Design (Pg & SD) 2 module was one of core programming modules offered to 1st year Engineering and Computer Science courses. This module was structured into two parts: one to deliver low-level programming with 68000 assembler and its programming language, and the other to *continue* to teach high-level C++ programming which students had studied from Programming & Software Design 1 (the prerequisite of the Pg & SD 2) in semester 1. In the first 4 weeks, lectures and tutorials were delivered to teach the 68000 assembler by one of the module teaching team, and from week 5 C++ programming was taught by the module leader (*Lecturer B*). Students were considered to have some understandings of basic C++ programming from the previous semester. From this module, students were expected to learn pointers, dynamic memory allocation, data structure and etc., and to apply them in programming.

Lecturer B considered facilitating learning with this module difficult with three reasons. First of all, the Pg & SD 2 module was taken by a large number of students from various courses with diverse background knowledge and interests. Secondly, programming itself is difficult to teach and learn due to the abstract and dynamic nature of the domain, which was shared by *Lecturer N* at Napier University and many others. Thirdly, it was found that some students entered university with insufficient knowledge in mathematics, which caused fundamental problems with understanding programming and articulating a solution. To improve the teaching and learning situation with the module, *Lecturer B* felt a need to find a means to offer more support to students in tutorials and to encourage them to take some control over their learning: 'Checking each student's work during a tutorial takes a lot of time and we can only answer one question at a time. ... Students ask same questions repeatedly without trying to find a solution by themselves during and after tutorials, which takes much time from tutors, and as a result some students can not get sufficient supports from tutors unless they voluntarily seek help.' In addition her teaching experiences suggested that some students with low self-confidence became de-motivated to learn but did not seek help when they had problems of coping with their studies.

Lecturer B considered that integrating IMM courseware for both teaching and learning could solve the problems identified with the module at Brunel University through 1) assisting student learning with visually enhanced materials in lectures and for independent learning; 2) encouraging and motivating students to seek their own solutions from IMM courseware in tutorials and during independent studies; students to think by themselves for problem solving; 3) providing more supports by teaching staff reducing the time to answer repeated questions; and 4) supporting independent learning offered by the strengths of IMM.

7.2.3 IMM courseware (IMM C++) integration into the curriculum

Course materials were prepared separately for 68000 Assembler and C++ Programming. IMM courseware (IMM C++) was developed for the Pg & SD 2 module aiming to support students, particularly weak ones, to understand programming concepts and applying them in C++ programming. *Lecturer B* collaborated in designing and developing the content of IMM C++, and it was integrated for both lectures and tutorials from week 5 to the end of semester. IMM C++ consisted of: a resource-oriented material (R-IMM C++) containing information and a task-oriented material (T-IMM

C++) containing tasks. The first was used in lectures and the latter in tutorials. In case study 1, three different versions of the Task-oriented material (T-IMM OO) were developed and integrated into SD module at Napier University: with questions and tasks first version offering a model answer but no hyperlinks for direct access to related information in the Resource-oriented material (R-IMM OO), second version providing hyperlinks with questions or tasks, and third version displaying hyperlinks as part of feedback after students answered incorrectly or after they answered in case of open questions and design tasks. The results, reported in Section 6.5.2, suggested that the third version was most effective in supporting students' learning. Based on this result, only the third version was implemented and integrated for the Pg & SD 2 module. The integration of IMM C++, with other materials and tools, into the curriculum was summarised in Table 7-1.

Module components	Materials	Role & Description
Lecture Two 1 hour lectures per week	**R-IMM C++**	▪ A main teaching and learning material: contained resources for C++ programming ▪ Used to deliver lectures and to support independent learning
	Handouts	▪ Learning materials: In week 5, text books were recommended to students but no handouts were distributed in lectures. Later, handouts were given to students because there were strong demands for them.
Tutorial One 3 hour tutorial per week	**T-IMM C++**	▪ A tutorial and learning material (part of IMM C++). It contained questions and tasks, and direct access to R-IMM C++. ▪ Used as part of tutorial materials.
	Programming tasks	Paper-based programming tasks in tutorials. At the end of each tutorial students were to submit their solutions, and they were assessed.
	C/C++ compiler	MS DOS-based complier for C++ programming.[4]

Table 7-1 Integration of learning materials and tools in the Pg & SD 2 module

[4] Students found it difficult to use, and it was replaced by C++ Builder in the following semester.

Lectures were scheduled for every week, but tutorials were scheduled once every two weeks. For tutorials, students were divided into 6 groups, and each group had 3 hour tutorial per 2 weeks, and 3 tutors and 3 demonstrators were assigned for the tutorials. In case study 1, IMM OO was integrated with other paper-based learning material which provided detailed information and the information was built on the content of IMM OO; they both were tailored to support each other.

However, R-IMM C++ in this study was prepared as a main teaching and learning material along with recommended text books. Students requested to have handouts (paper-based materials), and they were soon prepared and distributed after lectures. Unfortunately, the content in handouts was not prepared to enhance student learning with IMM C++. For tutorials, T-IMM C++ was integrated in tutorials with paper-based programming tasks. In the instruction for each tutorial, *lecturer B* specified relevant resources in R-IMM C++ and which units in T-IMM C++ to do. The programming tasks were assessed, which was later found to have influenced students' use of IMM C++ negatively.

Following the finding in case study 1, reported in Section 6.6.4, that teaching staff's attitudes to and preparation for using IMM in tutorials affecting student learning with it, IMM C++ was introduced to the teaching staff in advance; in the beginning of the semester *Lecturer B* e-mailed other teaching staff requesting to evaluate it and to return feedback on it. In an interview, *Lecturer B* reported that the feedback from the teaching staff was very positive.

7.2.4 Research methods

A mixture of qualitative and quantitative methods was used to collect broad and in-depth data.

A. Questionnaire surveys

To explore students' learning experienced with IMM C++, three questionnaire surveys were conducted at three different stages: one in week 7, the second at the end semester, and the third in the following semester. At the end of a lecture, a questionnaire was handed out and students spent approximately 20 minutes on each (used the same questionnaires used at case study 1 with the module changed). The third was carried out as a follow-up study in case study 3 (Appendix 11).

B. Tracking files

To collect records of how students used IMM C++, it was programmed to trace and record how students used it such as the user ID, navigation paths, durations of each page, how many times "more" information on each content page, hyperlinks, animations and extra features were accessed and etc.

C. Interview

To investigate how students and teaching staff experienced teaching and learning of the module with IMM C++, i.e. students' approaches to learning with it, and to identify benefits of integrating it for both teaching and learning, interviews were conducted with students and teaching staff. On 19^{th} of March and 14^{th} of May, 25 students and 3 teaching staff were interviewed. In the following semester 27 students interviewed in October 2001 and 8 were interviewed in January 2002. All interviews are transcribed by the author.

D. Observation

Observation was conducted in lectures and tutorials every other week from week 5 until the end of semester 2. It was aimed to observe students using IMM C++ in actual teaching and learning processes: how students were using IMM C++ in the learning environment, if it promoted interactions between the tutor and students, and etc. In addition, *Lecturer B* recorded students' attitudes and behaviours during the semester.

7.3 Data collected and data analysis

Data collected

The data was collected from this study in semester 2 of 2000/2001 and the follow-up study in semester 1 of 2001/2002. The summary of how many students participated in questionnaires and interviews in case study 2 is presented in Table 7-2.

Methods	Total	QS1 & QS2	QS1 only	QS2 only
Questionnaire 1 (QS1)	59	31	28	
Questionnaire 2 (QS2)	48	31		17
Questionnaire 3 (QS3)	35	8	9	1
Interviews (March & May 2001)	25	16	2	4

Table 7-2 Summary of student participants of questionnaires and interviews

For questionnaire 1, all 59 students were identified but for questionnaire 2, 7 students did not write their names. There is a possibility that these 7 students answered questionnaire 1 as well. In addition, 27 students were interviewed in the following semester: week 4 and 5 in October 2001 and week 14 in January 2002. Students' performance with this module and Pg and SD 1 in previous semester was assessed to explore the effects of integrating IMM C++ further on student learning of the Pg & SD 2 module because data from interviews and open questions suggested that it was the most important change from their learning of C++ programming in the previous semester.

Students had taken the Pg & SD 1 module in the previous semester, and their performance were compared with theirs from the Pg & SD 2 module. Table 7-3 summarises the results.

Grade	A (70-100)	B (60-69)	C (50-59)	D (40-49)	E (35-39)	F (0-34)	Total	Mean	Std.
Pg & SD 1	**9**	**14**	**20**	**22**	**22**	**33**	**120**	**45.0**	**20.8**
Pg & SD 2	**14**	**16**	**18**	**15**	**11**	**25**	**99**	**48.9**	**20.4**

Table 7-3 Summary of the Pg & SD 1 and Pg & SD 2 modules (%)

The mean and Standard Deviation of the Pg & SD 1 module were 45.0 and 20.8, and as for Pg & SD 2 module they were 48.9 and 20.4 respectively. In semester 2, the students' performance improved significantly, and this may be a result of using IMM courseware for their learning. The data was further analysed in relation to other variables and the results are reported in Section 7.4.3, which revealed that there had been significant performance improvement from weak students who had been in lower grades, Grade E and Grade F in particular for the Pg & SD 1 module.

Data analysis

The data collection and analysis for this study were complex and difficult due to the nature of classroom-based research. First of all, student learning experience with IMM C++ was not an isolated learning event from which their learning outcomes could be measured in relation to certain experimental factors. It was embedded in and became part of the learning environment in which students were engaged in learning. Secondly, case study 2 and its follow-up study were conducted during two semesters. Various methods were used to collect data at several different stages of these studies. Under the circumstances it was not feasible to collect data for all students.

The focus of data analysis was to examine the impact of IMM C++ in student learning: students' performance and perception of their learning experience. At first, it was difficult to identify if and how IMM C++ facilitated student learning because their learning experiences with it varied and the data collected were extensive. Three different approaches taken in the data analysis enlightened and illustrated student learning with IMM C++ in the learning context, and they are:

- **Analysis phase 1: perceptions & use of IMM C++ vs. learning outcomes**

The results from this analysis provided the overview of student learning with IMM C++. Certain factors which seemed to have affected student learning were identified, but the relationships between them or with students' learning outcomes were not clear at this phase.

- **Analysis phase 2 : marks in the Pg & SD 1 vs. perceptions & use of IMM C++**

The results indicated that students with low marks in the Pg & SD 1 module perceived their learning with IMM C++ more positively, and many improved their performance. However, the variations in their learning outcomes among the students who used IMM C++ for independent learning were not clearly answered.

- **Analysis phase 3 : marks changed vs. perceptions & approaches to IMM C++**

Students' perceptions and approaches to using IMM C++ were specified and investigated in terms of their performance changed between the Pg & SD 1 and Pg & SD 2 modules. The results enlightened student learning experiences with IMM C++: the effectiveness of it in the environment in relation to students' approaches to it.

7.4 Results

Section 7.4.1 reports students' learning perceived with C++ programming and IMM C++. Section 7.4.2 reports what affected students' learning with IMM C++: students' characteristics, prior experience with IMM, attitudes to a new technology and etc. Students' approaches to using IMM, their learning outcomes, and the benefits of IMM in the context realised are reported in the following three sections.

7.4.1 Overview of student learning experience with IMM C++

Overview of students' perceptions learning of C++ programming with IMM C++ will be presented before discussing in detail if and how integrating IMM C++ for teaching and learning supported students' learning through examining how students experienced learning with it and what benefits they gained. As reported in Section 7.2.2, students studied C++ programming in the previous semester with paper-based materials. To determine whether integrating IMM C++ contributed to improve students' perceptions of learning with the domain, in week 7 and at the end of semester 2 students' perceptions were questioned.

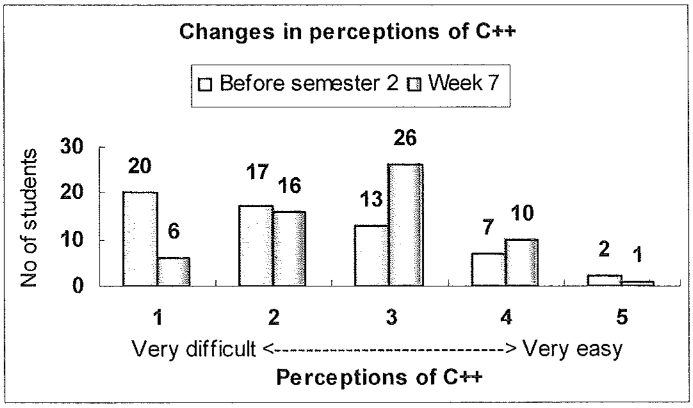


Figure 7-1 Students' perceptions with C++: prior to semester 2 and week 7

As shown in Figure 7-1, there was a positive change in students' perceiving the difficulties of C++ between prior to semester 2 and in week 7. Two plausible reasons considered for this change were: one, IMM C++ integrated for teaching and learning and the other, students' familiarity to the domain from their studies of it in semester 1. To determine which one contributed more to this change, students' perceptions of the domain was questions again at the end of semester 2.

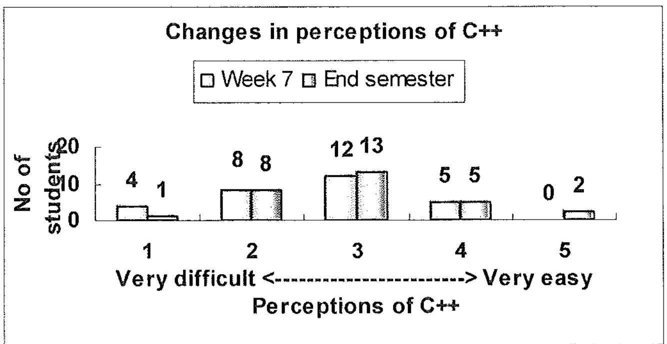


Figure 7-2 Perception of C++: week 7 and end semester (n=29: students who answered both questionnaires and no responses (n=2) were removed)

As shown in Figure 7-2, 8 weeks later students' perceptions of C++ changed only slightly positive. This indicates that students' prior experience with C++ may not have contributed how students' perceived C++ programming in week 7. Rather their perceptions of the domain were influenced by how they were experiencing their learning with it in lectures and tutorials, and from their independent learning. As IMM C++ was an integral part of the educational context in which students were engaged in learning and other contextual factors were similar to the previous semester, assessment, departmental policy and etc, it could be assumed that their experience with IMM C++ affected how they perceived the domain. This assumption was supported by students' comments during interviews.

Many reported that having IMM C++ in lectures and for independent learning *eased* and *helped* their understanding with C++ programming concepts, and some even argued that IMM should have been used from the previous semester.

Students' self-reported enjoyment of studying the module and IMM C++

In week 7, 32% of students (19/59) rated their enjoyment of the module to 4 or 5 (more than average), and the same number of students (32%) graded their enjoyment to 1 or 2 (less than average). At the end of semester only 21% of students (10/48) rated their enjoyment to 4 or 5 whereas 34% rated it to 1 or 2. When questionnaire 2 was answered, students were due to submit their major assignment. The pressure could be a reason for the reduced number of students on 4 and 5 scale points.

Closer examination into students who participated in both questionnaires presented somewhat different result. Students' self-rated enjoyment with the module actually increased. In week 7 39% of students (12/31) rated it less than average (1 or 2), which was reduced to 29% (9/31) at the end of semester. The percentage of students who enjoyed it more than average (4 or 5) was similar, 29% and 26%. To determine whether students' perceptions of the domain and their self-reported enjoyment of the module were associated, Chi-square was performed. Between these two, a significant association was found (χ^2 = 23.62, p=0.05 (1-sided)).

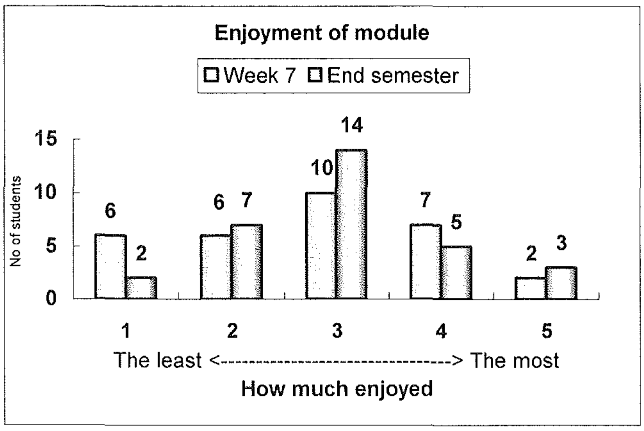


Figure 7-3 Students self-rated enjoyment of the module in week 7 and at the end semester (n=31)

Data from usability assessments at the end of semester suggest that using IMM C++ in lectures and tutorials contributed to how much students enjoyed the module. More than 50% of students reported that they enjoyed learning with IMM C++ in both lectures and tutorials, and more from using them for independent learning.

Category	A/SA	N	D/SD	M
A. Enjoyed IMM C++ in lecture	51	33	16	
B. Enjoyed IMM C++ in tutorial	51	26	16	7
C. Enjoyed T-IMM C++ for independent learning	66	21	9	4
D. Enjoyed R-IMM C++ for independent learning	63	26	7	4
E. Found R-IMM C++ beneficial	58	21	19	2
F. Found T-IMM C++ beneficial	56	21	21	2
G. More IMM for lecture	52	26	19	7
H. More IMM for tutorial	42	33	18	7
I. More IMM for learning	63	23	7	7
J. Use to revise	70	19	4	7

Where A = agree, SA = strongly agree, N = neither agree nor disagree, D = disagree, SD = strongly disagree, M = no response
All figures are percentages

Table 7-4 Usability assessment at the end of semester (n = 43)

In addition, many students in interviews mentioned that IMM C++ helped them enjoy learning C++ more. One of students' in interviews commented:

> *B01S1:* ... Actually, I do [enjoy]. I think it [IMM C++] should have been come in the first semester. That would have been better. Because you know people had difficulties with C++ because everything was paper-based, quite ambiguous first semester. That's what I thought. But I think if we had used this in the first semester, people would have enjoyed doing C++ more.

Excerpt 7-1 Student's comment on IMM needed to be used from the first semester

Data from case study 1, reported in Section 6.6.2, showed students' more positive responses to their self-rated enjoyment of SD1 module with IMM OO. Only 15% of students (9/59) rated their enjoyment to 1 to 2, and 53 % of students (31/59) to 4 or 5. Comparison of students' responses and their learning environments between the two studies pointed out four factors which were likely related to these results: introduction to IMM courseware, frequency of use, assessment in tutorial tasks and integration with other materials.

Firstly, IMM OO was introduced in the first tutorial and students started to learn object-oriented development subject matter from the beginning with it. In this study IMM C++ was introduced in week 5, and some students already began to miss tutorials and became unaware of the existence of T-IMM C++. Second possible factor is students' contacts with IMM courseware supported by and in the learning environment. In case study 1, students used IMM OO at least once a week in tutorials excluding their independent use. Students in this study had less encounters with IMM C++ for learning due to once every two weeks tutorial timetable, and third factor can be associated to in the assessment of a paper-based task in each tutorial. For each programming task, 5 marks were granted. The assessment of tutorial tasks appeared to motivate some students to focus on the programming task only rather than to test and reconceptualise their understanding of C++ concepts first with IMM C++ in tutorials.

Closer examination into the second and third factors, will be discussed in Section 7.4.5, revealed that they affected students' approaches to using IMM C++, which influenced their perceptions of their learning with it and learning outcomes of the module. The last factor inferred from qualitative data analysis was the integration and distribution of course materials. In case study 1, reported in previous chapter, IMM OO was developed and installed before the semester started and students could access both R-IMM OO and T-IMM OO from the beginning. In this study for the first couple of weeks students had IMM C++ and text books for learning, and later handouts were distributed because students complained about not having them. In terms of delivering and distributing IMM C++, students did not have an access to the whole IMM C++ in the beginning because the development of IMM C++ was carried on during the semester although it was ready at least a month in advance for lectures.

Students' preferences of IMM use, teaching and learning methods

Students' preferred use of IMM courseware was questioned in week 7: both for teaching and learning, independent learning only or teaching only. Sixty six percent of students (39/59) responded that they preferred to use IMM for both teaching and learning. Fifteen percent (9/59) preferred to use it as an independent learning material only, and 8% (5/59) did as a teaching aid. At the end of semester 88% (42/48) responded that IMM C++ was an independent learning material and teaching aid. These results in students' preference of IMM use and their perceptions of IMM C++ may be an indication that they considered having IMM C++ for teaching and learning satisfactory.

Students' preferences of teaching and learning methods

The question was intended to identify which method students preferred for their teaching between traditional method and IMM. As displayed in Figure 7-4, 55% (23/45) preferred IMM, 33% (15/45) did traditional teaching one and 13% (6/45) responded both traditional and IMM.

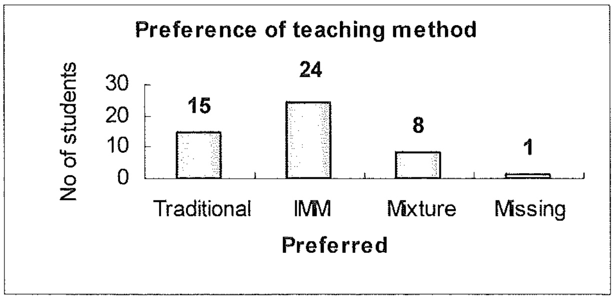


Figure 7-4 Students' preferred teaching methods at the end semester (n = 48)

As shown in Figure 7-5, majority of students – 85% (41/48) preferred to have mixture of traditional paper-based and IMM-based learning methods. Ten percent (5/45) were inclined to IMM-based one and 4% (2/45) were to traditional one.

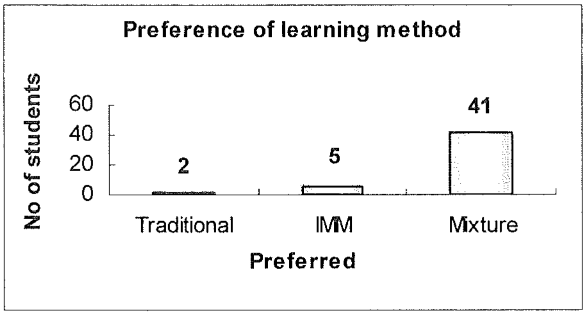


Figure 7-5 Preferred learning methods (n = 48)

7.4.2 Characteristics of students and their learning experience with IMM C++

Students' responses from questionnaire 1 in week 7 and interviews in this study revealed that students' previous experiences with IMM affected their learning with IMM C++ positively: sought to use it more actively and perceived their learning with the module more enjoyable. To determine how much students' prior experience with IMM affected their learning with IMM C++, their responses were analysed with how they perceived their learning experience with IMM C++ and how they used it.

Prior experience of IMM

Questionnaire survey result in week 7 revealed that 46% of students (27/59) have experienced using IMM materials either from a module, independent studies or both. As displayed in Figure 7-6 (left), 19% of students (11/59) had a previous experience of taking a module with IMM materials.

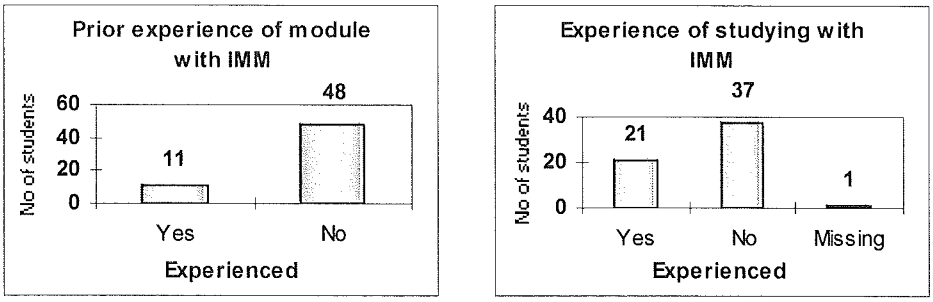


Figure 7-6 Experience of a module with IMM

This result was similar to case study 1, in which 20% of students had an experience of taking a module with IMM. And 36% of students (21/59) responded that they had used IMM materials for their independent learning. This result was also similar to case study 1, in which 38% of students had prior experiences of using IMM for independent studies. Five students (8%) replied that they had experienced both[5]. However, 3 among 21 students, who responded that they used IMM for independent learning, cited Photoshop or Flash as IMM learning materials which are not but tools to create graphics or animations.

How students' prior experiences influenced their perceptions of and approaches to learning with IMM was explained by some students' comments during interviews. Having mentioned that many students were not familiar with multimedia-based learning and some were even reluctant to try, a student replied that:

[5] Students who used IMM for independent learning showed inclination to have IMM courseware for both teaching and learning (18/21) or independent learning (3/21). Students whose experience with IMM was from taking a module responded similarly: majority for both (9/11), one for independent and the other one for teaching only.

> *B01S2:* I had never used multimedia materials for my studies. I only used traditional paper-based learning materials before this module, so I complained to some of my friends outside the university. They said, *"Try it. If you don't like it, then delete it."* I tried it at home. I do not like to say, but I liked it. I liked it very much. When I played animations again and again, *I could remember what the lecturer explained and it really helped me understand the concepts.* After that, if my classmates complained about the material, I said, "Try it. If you don't like it, delete it.

Excerpt 7-2 Student's comment on initial reluctance to use IMM and enjoyment found after using it

As implied in this student' comment, some students in interviews mentioned that initially they were reluctant to try IMM C++ for learning because it was new to them. Not only students' prior experience with IMM affected their learning with IMM C++ but their openness to a new technology did it as Baylor and Ritchie (2002), in their study investigating integration of technology to facilitate learning, found how both teachers and students' openness to a new technology affects student learning with it. These two, students' prior experience with IMM and their attitudes to a new approach (having IMM C++ for teaching and learning in this study) were further explored to determine how much they were related to students' approaches to learning with IMM C++ and if they affected students' learning outcomes. The latter will be further discussed in Section 7.4.4.

Students' perceptions of IMM C++ helping understanding with C++

As Figure 7-7 shows, 68% of students (40/59) considered that using IMM C++ for both teaching and learning could improve their understanding with C++ programming. At the end of semester 2, 58% (28/48) considered that it had helped their understanding with C++ programming.

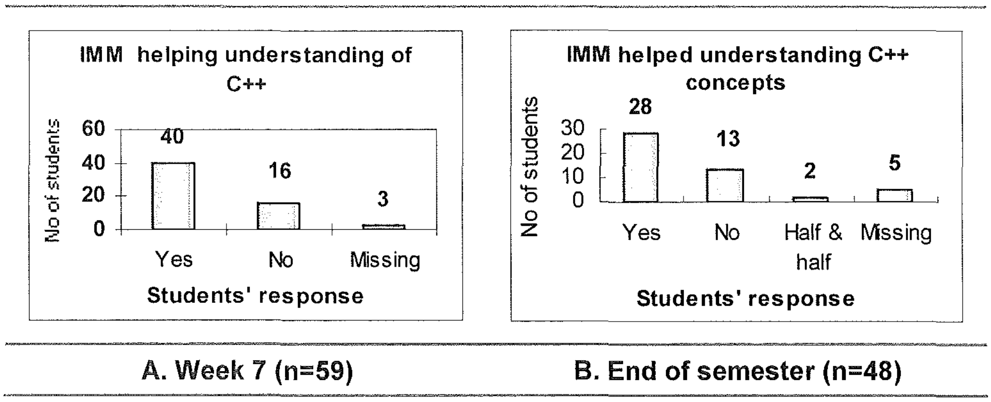


Figure 7-7 Students' responses of IMM C++ could help understand C++ programming in week 7 and IMM helped understand it at the end semester

In week 7, 27% of students (16/59) responded negatively for the question about 'having IMM C++ could improve their understanding with C++ programming'. At the end of the semester, the perceptions of 5 among the 16 students, who had replied negatively, changed from negative to positive. However, among the 14 students, who answered negatively at the end semester (right graph in Figure 7-7), 5 students' perceptions had changed from positive in week 7 to negative at the end semester.

To determine whether students' prior experiences with IMM C++ affected their perceptions of IMM C++ for learning, students' responses were explored with other variables. Students with a prior experience of using IMM materials regardless how they had used them responded more positively to IMM C++ helping their learning.

First of all, all 11 students in Figure 7-6 (left) cited that using IMM C++ for both teaching and learning could help understand C++ programming (Figure 7-7), and 81% (17/21) in Figure 7-6 (right) replied positively as well and only 19% (4) responded negatively to the question. However, 2 of them were ones who citied Photoshop or Flash for IMM materials used for their learning. Excluding these two students, 90% of IMM experienced students perceived IMM C++ could help their learning of C++ programming whereas 57% of students without a prior experience with IMM responded positively. However, at the end of the semester students' perceptions on IMM C++

having helped understanding C++ slightly changed. Students' prior experience with IMM was no longer associated with their perception of IMM C++ helping their understanding with C++. The change is summarised in Table 7-5.

Prior experience with IMM	IMM C++ can improve understanding C++ *in week 7*			IMM C++ improved understanding C++ *at end semester*			Total
	Yes	No	Not sure	Yes	No	Not sure	
Yes	10	2		5	5[6]	2	**12**
No	10	2	7	14	5		**19**
Total	**20**	**4**	**7**	**19**	**10**	**2**	**31**

Table 7-5 Summary of students' views on IMM C++ for learning

Students' responses from questionnaire 1 and 2 were further divided based on the data from interviews. For example, students who showed their doubts to the question 7 even though they chose "yes", were categorised to "not sure" rather than "yes" group.

Interesting results in Table 7-5 are that the perceptions of some students with prior experiences with IMM changed from positive to negative while some without prior experiences changed from negative to positive. Students' comments during interviews enlightened what caused the changes. For the positive change in students with no prior experiences was, as expected, affected by their using IMM C++ for learning and experiencing its supports for learning. In terms of the negative change in some students with prior experiences with IMM, it may be influenced by their expectations of IMM courseware. IMM C++ did not contain sufficient information for C++ programming as its primary aim was designed to support students to grasp understanding of C++ concepts, and students needed to use other learning materials. In particular, some showed dissatisfaction with IMM C++ because it did not provide examples illustrating whole programmes but parts illustrating C++ concepts in programme examples.

[6] Three students among them got better marks: 73->77, 69->80 and 40->45, one had slightly lower mark: 21->18, and the other did not submit the assignment at the time of the evaluation.

A student in interviews described it as: "It was helpful to understand fundamental concepts with C++. But it was not *that* helpful. I still needed other learning materials." Because of this some considered that it was not as helpful as they initially considered it to be or it had to be. One other possible reason can be that IMM materials students used in the past for independent learning were primary courseware which contained a large amount of learning resources, and IMM C++ did not meet up to the expectations of these students. What students found unsatisfactory are further discussed in Section 7.4.7.

Prior experiences with IMM, through affecting students' perceptions of helpfulness of IMM C++ for learning, influenced how and when they actually used IMM C++. Students with prior experiences with IMM initiated to use IMM C++ more actively in tutorials and for independent learning, which contributed to students' academic performance. Detailed descriptions of students' prior experience with IMM and their learning outcomes are presented in Section 7.4.5.

In terms of students perceiving IMM C++ for helping their learning, there is a possibility that students underestimated how much it helped their understanding with C++. The dialogue was taken from a conversation between a student and *Lecturer B*.

> *B01S3:* Last semester, it was *difficult to understand the C++ concepts, especially flowchart*, but this semester the concepts were easy to understand but difficult to apply [he meant in the assignment]."
> *TK:* You do understand pointers and structures pretty well, right?"
> *B01S3:* Yes, but *the pointer is easy to understand, isn't it*?" ...
> *B01S3:* I am proud. I even played animations in Pointer lessons several times to understand better and finally I understood well."
> *TK:* Did you apply these concepts before starting the assignment?"
> *B01S3:* Yes, it was easy to do it. But the assignment was difficult to do because I didn't apply structures before.

Excerpt 7-3 Part of conversation between a student & *Lecturer B*: positive change in the student's perceptions of C++

As the conversation suggests, the student perceived Pointers and other concepts taught in semester 2 easy ones to understand because he came to understanding them easily. He considered 'flowchart' difficult because his learning experience with it was difficult.

This view was repeated by other students in interviews. As for most students it was the first time to learn the advanced C++ concepts, many perceived them as easy concepts to understand unlike ones they had learnt in semester 1. *Lecturer B* during interviews emphasised that IMM C++, particularly the animations embedded, eased and enhanced students' understanding with C++ programming.

7.4.3 Prior learning with C++ programming and use of IMM C++

As described in Section 7.2.2, this module (the Pg & SD 2) continued to teach C++ programming from the Pg & SD 1 module in semester 1. Most students, excluding a few elective students, in this study took the Pg & SD 1 module in the previous semester. Educational context for two modules was very similar; there were no significant changes between two modules in terms of the structure and timetable of the two modules, facilities and software used, i.e. C++ complier, and teaching staff. The only difference between them was integrating IMM C++ for lectures and tutorials in semester 2 instead of using paper-based materials. The educational context in case study 1 was similar to this study. Data from case study 1 revealed a significant correlation between students' academic performance between the SD 1B and the SD 2B modules at 0.001 level. Considering the similarities of the educational contexts for the Pg & SD1 and Pg & SD 2 modules, same students taking both modules and the result in case study 1,

It was assumed that if a significant change in students' performance between these two modules appeared, it could be contributed by integrating IMM C++ for teaching and learning. A paired T-test was performed to determine whether students' performance between the two modules could be considered independent from each other. A significant difference was found between two performance results (t = -2.44, p = 0.02).

A more significant change was found from students whose marks were under 60 in the Pg & SD 1 module (t = -3.73, p = 0.001), which may suggest that weak students benefited more from integration of IMM C++ for teaching and learning. Students' performance was further analysed with their perceptions of their learning experienced and their use of IMM C++ to determine how much students' perceptions were reflected on their performance.

Students' performance and their perceptions of learning

As summarised in Table 7-6, significant correlations were found between how students perceived their learning with C++ programming domain and their performance. The result from Pierson's correlation test revealed that students' perceptions of C++ programming prior to semester 2 was associated to their performance with the Pg & SD 1 module at 0.01 level. The same result was found between their perceptions of the domain during semester 2 and their performance with the Pg & SD 2 module. How much they enjoyed their learning with the module was related to their performance as well. The result is not surprising considering students' self-rated enjoyment of the module and their perceptions of the domain were associated at 0.05 level (Section 7.4.1).

Variables	**Significance**	**Effect**
Students' perceptions of C++ before semester 2 vs. the Pg & SD 1 performance in semester 1	0.01	0.47
Students' perceptions of C++ in semester 2 vs. the Pg & SD 2 performance in semester 2	0.03	0.307
Students' enjoyment of the Pg & SD 2 module vs. performance	0.02	0.327

Table 7-6 Correlations between students' performance and their perceptions of learning

To determine whether students perceived IMM C++ helped their learning and their performance was related, Pierson's correlation test was performed. A positive association was found at 0.06 level although it was not statistically significant. Analysis into students' prior experiences with IMM and their changes in perceiving IMM C++ helping their learning in week 7 and at the end of semester 2 suggested that some students' negative responses were due that their expectations of IMM C++ were not met. However, these students used IMM C++ from the beginning. Students' actual use of IMM C++, if and how they used it for learning, may be more closely associated to their performance more than their perceptions of it helping their learning, which will be discussed further in Section 7.4.5. Students' performance was further analysed to determine who and how integrating IMM C++ helped most.

Students' performance between the Pg & SD 1 and Pg & SD 2 modules

As summarised in Table 7-7 students' there was a significant change in students' performance between the Pg & SD1 and Pg & SD 2 modules. Particularly students' with lower marks in the Pg & SD 1 module obtained more improved learning outcomes than ones with average or high marks. The means for students in lower grades, E and F, became much higher whereas the means for students in high grade groups, A and B, became lower. To determine whether the change in each grade group was significant, a paired T-test was performed. Not surprisingly as students' performance between two modules appeared independent at 0.02 level, students' performance changes in each group was statistically significant: grade A & B at 0.01, grade C & D at 0.05 and grade E & F at 0.001 level.

Pg & SD 1 Grade	Pg & SD 1 marks			Pg & SD 2 marks		
	N	Mean	Std.	N	Mean	Std.
A (70–100)	15	78.2	6.3	15	66.4	15.9
B (60–69)	14	64.9	2.8	14	58.3	16.0
C (50–59)	20	53.7	2.7	18	45.5	18.4
D (40–49)	22	44.7	3.5	18	41.8	14.6
E (35–39)	10	**36.0**	0.8	8	**40.3**	21.0
F (0–34)	33	**20.6**	10.2	19	**43.5**	20.1
Total	**114**	**45.4**	**20.7**	**92**	**49.3**	**20.1**

Table 7-7 Students' performance change between grades from the Pg & SD 1 and Pg & SD 2

To explore the change in students' performance between two modules more clearly, it was further examined in their grade groups, which is displayed in Table 7-8.

	Pg & SD 2						
Pg & SD 1	**A (70–100)**	**B (60–69)**	**C (50–59)**	**D (40–49)**	**E (35–39)**	**F (0–34)**	**Total**
A	9	2	**2**		**1**	**1**	15
B	**4**	4	2	**2**		**2**	14
C	**1**	**2**	7	2	**1**	**5**	18
D		**3**	3	5	**2**	**5**	18
E		**2**	**1**	2		**3**	8
F	**1**	**5**	**2**	**2**	2	7	19
Total	15	18	17	13	6	23	92

Table 7-8 Grade changes between the Pg & SD 1 and the Pg & SD 2

The results in Table 7-8 suggest two areas to investigate; one in the marks increased in E and F grades; the other in the marks decreased in C and D grades. To investigate if using IMM C++ was responsible for this positive change, students' responses to the usability of IMM C++ and data were analysed in relation to their marks from the Pg & SD 1 module.

Students' performance and IMM C++

At the end of the semester usability assessment was performed as part of questionnaire 2 to determine how effective and supportive students perceived of IMM C++ in the educational context. Students' responses are summarised in Table 7-9.

More detailed analysis into students' responses of the usability assessment revealed that students in low grades from the Pg & SD 1 module responded more positively to some questions than students with high grades: A. enjoyed IMM C++ in lectures, G. more IMM for lectures, H. having good understanding of C++ programming, M. control of learning, and N. animation helping learning. For example, for enjoying IMM C++ in lectures, whereas 23% of students in A and B grades (3/23) agreed to the question 73% (8/11) students in E and F grades either agreed or strongly agreed. Similar results were found from students' responses to the other 5 questions. For the rest of the questions, students' responses were similar.

Question	A/SA	N	D/SD	M
A. Enjoyed IMM C++ in lecture	51	33	16	
B. Enjoyed IMM C++ in tutorial	51	26	16	7
C. Enjoyed T-IMM C++ for independent learning	66	21	9	4
D. Enjoyed R-IMM C++ for independent learning	63	26	7	4
E. Found R-IMM C++ beneficial	58	21	19	2
F. Found T-IMM C++ beneficial	56	21	21	2
G. More IMM for lecture	52	26	19	7
H. More IMM for tutorial	42	33	18	7
I. More IMM for learning	63	23	7	7
J. Use to revise	70	19	4	7
K. Easy to use	70	23	7	
L. Easy to search	73	16	9	2
M. Control of learning	32	35	26	7
N. Animation helping learning	54	26	16	4
H. Now have good understanding of C++ programming	34	40	19	7
I. Hyperlink: problem solving	41	44	4	11
J. Hyperlink: helping understanding abstract concepts	42	42	7	9
Where A = agree, SA = strongly agree, N = neither agree nor disagree, D = disagree, SD = strongly disagree, M = no response *All figures are percentages*				

Table 7-9 Usability assessments at the end of semester (n = 43): the order of questions – rearranged

These results can indicate that weaker students found visually enhanced lectures with IMM more helpful and having it for teaching and learning benefited their learning. During interviews students' comments on their learning experienced with IMM C++ supported this, one of their comments is:

> *B01S4:* I found it [IMM C++] quite beneficial. Yes, it helped me a lot at least. Last semester, I wasn't all that keen with programming stuff but now [I do]... and also trying to make sure this multimedia ... equipment help me to re-establish and understand it [C++] more than I used to...

Excerpt 7-4 A student's comment: interests in C++ programming improved with IMM C++

To investigate how and what parts IMM C++ played in relation to these two results, as a next step, students were re-categorised according to the change in their marks. They were divided into 4 groups based on how much their marks were increased or decreased.

The groups were further analysed with their responses from questionnaires and interviews to investigate what affected student learning positively and negatively, the results will be discussed in the next sections.

7.4.4 Learning with IMM C++ and performance

Data analysis into students' marks between the Pg & SD 1 and Pg & SD 2 modules, and their assessment of their learning with IMM C++ identified variations in student learning experienced with IMM C++ and their learning outcomes – perceived and obtained outcomes. Students were categorised into 4 groups according to how much their marks changed between the modules. Students' responses were analysed in each group to investigate if the variations in student learning with IMM C++ were related to the variations in students' learning outcomes: changes in performance and perceptions.

Four students groups classified by performance change between the Pg & SD 1 and Pg & SD 2 modules

Table 7-10 describes the classification of the 4 groups. The grading system at Brunel used 10 marks between grades (A-D). Based on this, an assumption was made on students' performance: increased or decreased more than 10 marks meant a significant change and it was used to categorise students.

Group	Descriptions
Much Increased (MI)	Students whose marks were increased more than 10 points or whose grade was changed with more than 5 marks increased.
Slightly Increased (SI)	Students whose marks were increased less than 10 points with no grade change.
Slightly Decreased (SD)	Students whose marks were decreased less than 10 points with no grade change.
Much Decreased (MD)	Students whose marks were decreased more than 10 points or whose grade became changed with more than 5 marks decreased.

Table 7-10 Groups categorised by marks changed

The number of students in each group and data collected are summarised in Table 7-11.

Research method	MD	SD	SI	MI	Total
Questionnaire 1	8	12	7	21	48
Questionnaire 2	10	10	7	10	37
Questionnaire 3	8	4	4	8	24
Interview (> = once)	9	10	7	13	39

Table 7-11 No of students in each group and data collected

The results presented in this section were derived from case study 2 and follow-up study in 3rd case study. As this study was conducted in a real classroom setting, neither did all the students participate in a research method, nor did every student participate in all the research methods used. Quantitative and qualitative data were used together to investigate student learning more thoroughly.

Students' prior experiences and attitudes to a new approach

Students' prior experience with IMM and their perceptions of learning with IMM C++ were discussed in Section 7.4.2. Data was further analysed to investigate relationships between these variables in relation to students' learning outcomes. Table 7-12 summarises students' prior experiences with IMM in each group.

Prior experience	MD	SD	SI	MI	Total
Yes	2	2	4	11	**19**
No	9	11	5	10	**35**
No of students	11	13	9	21	**54**

Table 7-12 Students' prior experience with IMM and changes in their marks [7]

More students in MI and SI groups had prior experiences with IMM than SD and MD groups. Some of students' comments in relation to their previous experiences with IMM were as follows:

> *B01S6:* ... first didn't like IMM, but later realised benefits and this time I have learnt a lot from the IMM material...

[7] As for students' prior experience with IMM, 64 students' data was collected. Among them, 10 did not have both marks from the Pg & SD 1 and Pg & SD 2 modules to compare: 5 with prior experience and 5 with no prior experience. Therefore, 54 students' data were analysed.

> *B01S7:* ...I didn't think much of it because I didn't understand the value of it [IMM he had used before this study]. I preferred ...
> *SH:* Paper-based materials?
> *B01S7:* Yes, exactly. Well, then I understood it's important. This makes graphically representative ... with multimedia to visualise...

Excerpt 7-5 Examples: prior experience with IMM affecting perceptions of IMM

As these comments suggest, many students without prior experience with IMM in this study had also showed initial reluctance to use IMM C++ for learning. Some of the students' comments were as follows:

> *B01S8:* I am still getting used to it now. I haven't used it before, so *I am still confused in a sense.* It will definitely take me a time to understand ...
> *B01S9:* This is my first time actually. *I am not very good at this....*
> *B01S10:* It's a new method of learning. So, I am not like entirely used to. *It's new. ... I am afraid...*
> *B01S11:* Before I came to Brunel, I'd never used a computer except for Word. To use this MM thing was quite big thing to me ... ...the first thing was, I didn't wanna use it. It was just *because it was on a computer, I didn't wanna use it.* Because it wasn't on paper, I didn't wanna use it. Because how I've just had it for ... like whole my life in education. And I just really did not wanna go near it ...

Excerpt 7-6 Examples: no prior experience with IMM affecting perceptions of IMM negatively

As the comments suggest, some students without a prior experience with IMM showed reluctance to use IMM C++ for learning. They initially perceived their learning with IMM C++ less positively than experienced ones. Their perceptions were positively changed at the end semester – after using IMM C++, but their performance was still associated to their prior experiences. The main reason was that some students with no prior experience were initially reluctant to use IMM C++; many started to use it for learning later than ones with prior experiences.

In addition, students' attitudes to a new approach affected their learning with IMM C++.

Table 7-13 presents students' attitudes and perceptions toward IMM C++ derived from qualitative data analysis.

Students' attitudes and perceptions	MD	SD	SI	MI	Total
Positive	1	6	1	12	20
Changed (Negative ->Positive)	2	1		2	5
Neither positive nor negative	3	1	5[8]		9
Negative	5	1			6
Total	**11**	**9**	**6**	**14**	**40[9]**

Table 7-13 Students' attitudes and perceptions with IMM C++

MI group perceived their learning with IMM C++ more positively, and they actually used it more in tutorials or for independent learning. SD group perceived it more positively than SI group. Two students in SI group were identified as confident learners; they did not consider types of learning materials important to them. A few other students exhibited independent learning styles: using books or the Internet for learning, but they used IMM C++ for learning. Some students in MD group kept their negative views on using IMM C++; it was found that many did not even try to use it for learning. Examples of positive comments are:

> *B01S12:* It was *easier to learn* ... pulled you along slowly and slowly and you could get every step as it was going. And there were like no big jumps either and I like the way it was related to the real world as well because it makes animation a lot easier to see ...
> *B01S13: In the lecture, you learn what she's talking about,* after that you can *always refer back to the same thing to build up your knowledge of that...*

Excerpt 7-7 Examples: students' comments on learning support from IMM C++

Examples of negative views are:

[8] Two students showed confidence in their learning and learning materials types used in a module seemed to signify little to them.

[9] As for students' attitudes and perceptions of their learning with IMM C++, 40 student data were collected for both the beginning and the end from the two questionnaires and interviews.

B01S14: ... give examples on the board to be copied by us...

B01S15: It was hard to take notes ...

B01S16: IMM cannot be the backbone of the course structure and teaching. More traditional methods are required to improve IMM...

B01S17: Did not find it helpful for independent learning ... due to personal preference for learning methods ...

Excerpt 7-8 Examples: students' negative comments on their learning with IMM C++

Students' negative comments were mostly based on personal preferences and perceptions of teaching and learning. Data analysed revealed that how students perceived their learning with IMM C++ was related to how they approached and used it. How and when they used it had an impact on their learning outcomes and the benefits gained from it. This is described in next two sections.

7.4.5 Approaches to using IMM C++ versus learning outcomes

Questionnaire 2 at the end of the semester identified how students used IMM C++: in lectures and tutorials only, as a main learning material or as a reference.

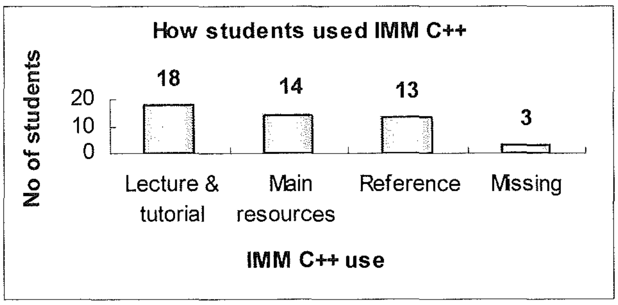


Figure 7-8 How students used IMM C++ (n=48)

Figure 7-8 shows that 50% of students (27/48) used IMM C++ as either main resources or reference materials for their learning. The other 38% (18/45) used it during lectures and tutorials. To closely examine the relationship between students' approaches to IMM C++ and their performance, their responses were compared between the 4 groups, and data was reanalysed to specify how and when students used it. Table 7-14 summarises the results. The analysis of interview and questionnaires data specified how and when most students used IMM C++, but for some students data was insufficient to determine when clearly. This was considered when students were classified.

The results presented in Table 7-14 show three significant differences between increased and decreased marks groups. The first was that the increased marks groups (MI & SI) used IMM C++ as the main learning material for the module and expanded their knowledge with other materials - books or handouts. More in MD and SD groups used it as a reference to access information quickly when they were studying with other materials.

When	How (objectives)	MD	SD	SI	MI	*Total*
From the beginning	Much used IMM C++ (both R-IMM and T-IMM) to revise what they learnt.			1	4	*5*
	Used the C++ IMM to build understanding of basic concepts with books for more information.		1	1	4	*6*
During the semester	Used as a main resource for learning[10]	4	3	2	4[11]	*13*
	Used in tutorials	2	2	1	3	*8*
	Used only as a reference	4	6	1	1	*12*
End semester	Used only for assignment.	1		2		*3*
Little or not used	Lectures only	6	2		1	*9*
No of students with data		17	14	8	17	56

Table 7-14 When and how students used IMM C++[12]

The second was that MI group used IMM C++ from the beginning to revise and to build understanding of concepts taught in lectures. Students were helped conceptualise C++ programming holistically; IMM C++ presented abstract C++ concepts, and how they were related and implemented in programmes with visual illustrations. That helped students conceptualise each concept, integrate them and apply them in programming

[10] In this category, students had used IMM C++ for their learning but unclear when each started to use it. They had started at some point in the semester.
[11] Two students had used T-IMM C++ as well.
[12] In MI group, students who had used IMM C++ for revision often used T-IMM C++ too. Most students, who had used IMM C++ in tutorials, had also used for independent learning or later for the assignment.

tasks. Others who used it as a reference, benefited from visually demonstrated concepts and examples but integration of them was not supported by IMM C++.

Third difference lies if and how students used T-IMM C++. Tasks in T-IMM C++ were designed to help students apply and test their understanding of C++ gained from lectures and R-IMM C++. Students were asked to do the tasks in T-IMM C++ in tutorials and recommended to go through R-IMM C++ if needed further understanding. However, there were variations in students' approaches to using T-IMM C++ in tutorials as well as in their learning with R-IMM C++.

In each tutorial, in a written instruction students were asked to do tasks in T-IMM C++ and a paper-based programming task. The first aimed to help students build a good understanding of C++ programming concepts and apply them in a task. The latter was to help students develop practical programming skills. Students were required to write a report on what they did in each tutorial and to submit their solution for the programming task, which was assessed. This assessment was partly responsible for the variations in students' approaches to IMM C++. Some students were much focused on accomplishing the programming task. They either skipped using IMM C++ or went through it superficially aiming to achieve the instruction given to them; their aim was to write in their report that they used IMM C++. These students were aware of the fact that the programming task was assessed but overlooked the underlying reason. When a student was asked why he was going through IMM C++ quickly without checking and correcting his incorrect answers, he replied:

> *B01S18:* We learned these last week already. We know these concepts."
> *SH:* But you answered incorrectly…
> *B01S18:* We have *a programming task to finish.*

Excerpt 7-9 Example 1: assessment in tutorials negatively affecting students' use of T-IMM C++

This comment was echoed by others in interviews, one of which is:

> *B01S19:* I went to tutorials. *I just didn't answer the questions* [in T-IMM C++] because she also had other questions [programming tasks] ...

Excerpt 7-10 Example 2: assessment in tutorials negatively affecting students' use of T-IMM C++

The assessment of each programming task was to encourage students to apply the concepts they learned either from lectures or IMM C++, but it resulted in discouraging some to spend their time on using IMM C++ for learning. One main objective of the design and integration approach in Chapter 4 is to improve student learning through enhancing the 'iterative' process of teaching and learning with IMM courseware. An ideal situation to benefit from this approach is that students use the T-IMM in a tutorial soon after a lecture, if not used for independent learning. This can enhance the learning process; furthermore, it can lead students to realise benefits with IMM courseware for their learning, with which they will become more encouraged to use it for learning.

In this study, C++ was taught from week 5 and students' first tutorial with it was scheduled in week 6 and 7. When students missed a tutorial, they ended up having one tutorial per month. In addition, the total number of tutorials scheduled for C++ was 4, and most students were focusing on their assignment at the 4th tutorial. Therefore, the iterative process in the integration approach to be supported by integrating IMM courseware into lectures and tutorials was not best supported in this learning context. This tutorial timetable compounded with the assessment of programming tasks seemed to be related to the variations in students' approaches to using IMM C++. Table 7-15 presents the summary of students' use of T-IMM C++ and hyperlinks identified.

MI group used T-IMM C++ and hyperlinks embedded in it more than other groups. They used it with R-IMM C++ to revise what they learnt in lectures or to build fundamental understanding of C++. Eight students unidentified if they used the T-IMM ++ in MI group at least used IMM C++ for learning from the beginning. A few in SD group used T-IMM C++, but only one used together with R-IMM C++. The majority in the group used IMM C++ as a reference material while they studied with other paper-based materials. Most in MD group did not use T-IMM C++. Two students used it in tutorials but did not use R-IMM C++ at all. This group did not use much of IMM C++ for learning; some used it as a reference material but none of them used T-IMM C++ together.

T-IMM C++ in tutorial	MD	SD	SI	MI	Total	Hyperlink use	MD	SD	SI	MI	Total
Identified	**15**	**13**	**5**	**9**	**42**	**Identified**	**14**	**13**	**5**	**9**	41
Yes	2	3	3	8	16	**Yes**	1	3	2	7	13
Little	1		1[13]		2	**Little**	1		2		3
No	12	10	1	1	24	**No**	12	10	1	2	25
Unidentified	**2**	**1**	**3**	**8**	**14**	**Unidentified**	1				1
Total	**17**	**14**	**8**	**17**	**56**	**Total**	**15**	**13**	**5**	**9**	42

Table 7-15 Students' use of T-IMM C++ and hyperlinks

The results in Table 7-14 and Table 7-15 indicate that students' learning outcomes were related to 'when' and 'how' they used IMM C++. Revising with R-IMM C++ enhanced their understanding of C++ taught in lectures, and applying their knowledge in tasks in T-IMM C++ and visiting related information when they identified their misconceptions helped them clarify and correct their misconceptions. It also affected the benefits students gained from IMM C++ in the context, which is discussed in next section.

There was another factor identified that affected student learning with IMM C++: using it in a group. In each tutorial, a few students groups sharing a compute together were observed even though there were available computers in the lab. In each tutorial, some students showed inclination to work in a group; they were reluctant to do a programming task alone. Although IMM C++ was designed as easy to use and

[13] Used it once in a group.

introduced in lectures, some were disinclined to use it on their own. These students had no prior experiences with IMM and it seemed to intensify their anxiety in using IMM C++ alone. Some students' comments taken from interviews are:

> *B01S20:* With my classmates. Usually in a group. Usually in a group. I need to, I need to be in a group because I am just struggling a lot ...
> *B01S21:* I am still getting used to it now. ... I was working with a group of friends. So, most of them have used multimedia before also. They hacked into, they know how to use it, so when we started it out, then I started enjoying the whole thing, reading the tutorial stuff like that.

Excerpt 7-11 Examples: students' use of IMM C++ in groups

A student in an interview pointed out a problem of using IMM C++ in a group, which is:

> *B01S22:* I think it [IMM C++] was useful. The problem is that the students, I think, had to do it on their own because *they were to sit down as a group, several classmates together just working on the actual thing, they will not take it seriously*. Just ask a teacher in front of them to explain to them. So, I think it's useful if you are on your own and want to test yourself, and then you can learn by that way. But not in a group...

Excerpt 7-12 A student's comment on problems of using IMM C++ in a group

The results in this section emphasise the importance of designing a learning context that can optimise the effects of IMM courseware for learning. Next section presents the learning supports offered by IMM C++ in the learning context, derived from the benefits students reported from their learning with it

7.4.6 Benefits of integrating IMM C++ for teaching and learning

As part of investigating what benefits students gained from IMM C++ in the learning context, their views on learning with it were explored; students were asked if they could learn from it independently without a tutor.

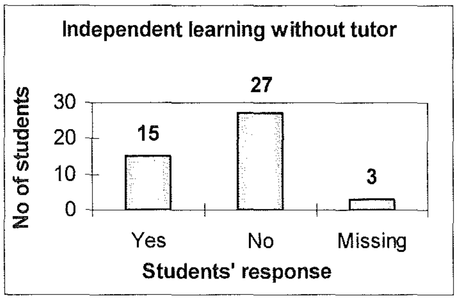


Figure 7-9 Learning from IMM C++ without tutor

At the end of semester 2, 33% of students (15/45) responded that they could learn from IMM C++ without a tutor whilst 60% (27/45) answered negatively. Two students in "Missing" answered "yes & no" commenting that there were occasions requiring help from tutors even with IMM C++.[14] Observations and interviews in this study and case study 1 showed that students did not require much help from their tutors to use either IMM C++ or IMM OO. Most students solved the tasks in T-IMM through finding their own answers with the feedback (model answers and hyperlinks for direct access to related information in R-IMM). The reason for the students' responses for this question was revealed from the interviews with students; tutor presence was more valued for reassuring them that they had help available.

Can learn from IMM C++ without a tutor	MD	SD	SI	MI	Total
Yes	8	2	1	1	12
No	2	7	4	9	23
Not all the time		1	1		2
Total	10	10	6	10	36

Table 7-16 Independent learning from IMM C++ without a tutor

As discussed in Section 7.4.5, fewer students in MD group used IMM C++ for learning. When they used it, was mostly as a reference or for their assignment at the end semester. However, more in MD group responded that they could learn from it without a tutor.

14 IMM C++ did not contain sufficient information for students to study the module only with it as it was primarily designed to support low and intermediate level students to grasp a good understanding of C++ programming.

These responses did not imply that MI, SI and SD groups could not learn from it independently. As described, few students showed difficulties in using IMM C++.

It rather implies that students in the latter groups experienced and were more aware of benefits from having it for both teaching and learning. Students' responses indicated that ones who used IMM C++ for learning after lectures realised benefits from its integration into the curriculum for teaching and learning, and from the content design, in particular visualisation (see Table 7-14). Students who used T-IMM C++ in tutorials became aware of the learning supports from its architecture: tasks and hyperlinks to related information in R-IMM C++ (see Table 7-15). They realised their misconceptions while solving tasks in T-IMM C++ and corrected them with information provided through hyperlinks.

Learning supports vs. "when" and "how" students used IMM C++

As Table 7-14 and Table 7-15 indicate, more students in MI group used IMM C++ to revise what they learned or to build understanding of C++; and from the beginning. Variations in the benefits students gained from IMM C++ were found to be related to these 'when' and 'how' students used it for learning. The benefits students reported were summarised in Table 7-18. A primary difference between MI group, and SD and MD was that MI group constructed their understanding of C++ with IMM C++ first and then used other materials to expand their knowledge; many used it as a main learning material after lectures for revision and did tasks in T-IMM C++ in tutorials (Section 7.4.5).

SD groups used IMM C++, but they used paper-based learning materials as their main learning material and used it as a reference because it was easy to access information and presented visually enhanced descriptions of C++. SI group was divided between the two. Many in MI group reported benefits by the integration of IMM C++ into lectures and tutorials, and the courseware architecture with hyperlinks. Table 7-17 summarises learning support students reported from having IMM C++ in lectures and for learning.

	Benefits in lecture					Benefits for learning				
	MD	**SD**	**SI**	**MI**	**Total**	**MD**	**SD**	**SI**	**MI**	**Total**
Realised	5	9	3	13	**30**	5	8	7	15	**35**
Not initially but soon realised		1		3	**4**					
Realised but too late	1				**1**	2				**3**
Some	1		2		**3**	1	3	1[15]	1	**8**
Initially but changed to negative			3		**3**			1		**1**
Little or not realised	7	3	2	1	**13**	6	2	1	1	**10**
Total	**14**	**13**	**10**	**17**	**54**	**14**	**13**	**10**	**17**	**54**

Table 7-17 No of students who realised benefits of IMM C++

Most in MI group considered IMM C++ beneficial for both lectures and independent learning, but at east half in MD group viewed it beneficial in neither. Among them, only a few actually used it for learning. Table 7-18 displays the learning support classified.

Category	Description of Benefits	MD	SD	SI	MI	Total
Supports by Integration	Learning supported by integration of IMM C++ in lectures and tutorials. [1] Supported independent learning on things delivered in lectures (promoted recall and reflection); [2] Allowed to try things, could see the results and had hyperlink effects of detecting and correcting misconceptions /identifying areas with insufficient understanding. · Allowed to test what and how much she/he knew and to expand knowledge after that; · Clarified things when learning.	1	2	4	10	**17**
Learning supports	[3] Helped understanding concepts - easy, and quick to understand through animations.	4	7	3	6	**20**
	[4] Supported independent learning; control of learning		1	1		**2**
	[5] Offered easy information access.	2	1	1		**4**
Little help	[6] Little or not used IMM C++ for learning	7	2	1	1	**11**
Total		**14**	**13**	**10**	**17**	**54**

Table 7-18 Benefits gained with IMM C++ (Classified on students' descriptions)

Many who benefited the first [1] by the integration of IMM C++ into lectures and

[15] A student considered IMM C++ beneficial but only used it once in a group.

tutorials experienced the second [2] benefit supported by the architecture of IMM C++ in the learning context. Most students in MI and SI groups who experienced benefit [1] and [2] experienced benefit [3], [4] and [5]. Students who considered using IMM C++ beneficial reported visualisation easing and helping their learning for independent learning or in lectures. A few comments for each category are extracted from students' interviews. Students' comments on the benefits by the integration of IMM C++ for both teaching and learning are:

> *B01S23:* I mean it's nice to have them in lectures to look at while she is teaching. Well, when you are outside lectures, it helps because you can do your own private study from what was done during actual teaching time, so...
> *B01S24:* I think they are good.... Perhaps more such choice doing your own time as well, because you don't remember everything in the lecture and it's nice to have the software afterward as well to go through yourself. You learn, that's it.
> *B01S25:* I thought the best thing about it is, it kind of *immersed you in actual learning in it.* It's structurally ... went to the learning structurally, so you basically went through how you should be learning it and it guided you through how to learn it.

Excerpt 7-13 Examples: students' comments on the benefits of IMM C++ by the integration

A few comments on benefit [2] by having T-IMM C++ are:

> *B01S26:* Because they teach you like... *They actually question if you get wrong, you can go back to it and find out how come you got it wrong* and what... So, you can learn from that.
> *B01S27:* That was useful because if you do a question wrong, you can go through that [accessing the related information in the R-IMM], understand it, then carry on to next question to do that helped.

Excerpt 7-14 Examples: students' comments on the benefits of T-IMM C++

Comments on benefits from visualisation [3] are:

> *B01S28:* I found it *easier to understand* than when I first started because the actual multimedia stuff *showed the process, how that actually worked.*
> *B01S29:* One thing is the animation. Because *the animation makes it very*

> *simple to understand things* like....... it makes you see what is really going on in the computer and that makes it very useful, I think for me.
> *B01S30:* it makes you try things and you can see what your programs are like on spot ... it just *shows you step by step things*. I like that.

Excerpt 7-15 Examples: students' comments on the benefits of T-IMM C++

Comments on other benefits for independent learning [4] are:

> *B01S31:* The fact that you could *use on your own pace*. The fact that you could use on your own pace basically.
> *B01S32:* I found help from animations and diagrams and etc. etc. But primarily the fact that you can sit on your own time, *go over bits needed go over again*. Go through it without needs to push about that.
> *B01S33:* I think the key was *I was able to use it at home*. That was really a big thing for me.
> *B01S12:* I think it was easier to learn because I've been so used to reading stuff out of books, trying to find something that I want. *It was a lot easier just to see it straight on the screen*, umm, I was like quite happy as well because it was straight up into show bits as well. ...I like the way it was related to the real world as well because it makes picture a lot easier to see.

Excerpt 7-16 Examples: students' comments on independent learning support from IMM C++

B. Learning supports for independent learning and in lectures

Students' responses of the learning supports they had with IMM C++, are categorised in Table 7-19. Students were counted for each category. Table 7-20 summarises benefits IMM C++ in lectures offered. The main strength was visually presenting C++ programming concepts and programming process.

Key strengths of IMM C++ for independent learning	**MD**	**SD**	**SI**	**MI**	**Total**
· Independent learning supports	6	7	6	15	**34**
· Control of learning	2		3	5	**10**
· Interactivity	2	2 [16]	1	5	**10**
· Visualisation	5	8	3	11	**27**
· Accessibility		2	2		**4**
· Easy information Access		1	2	3	**6**
IMM C++ beneficial for learning: 44 (Table 7-18)	**8**	**11**	**9**	**16**	

Table 7-19 Independent learning supports from IMM C++

[16] A student considered 'interactivity' as the key strength of having IMM C++ but mentioned not 'enough' and desired to have more content added.

Learning supports of IMM C++ in lecture	MD	SD	SI	MI	*Total*
· Gave clear, helpful and easier to conceptualise concepts through verbal explanation with visualisation	1	3	2	5	***11***
· Presented visually enhanced lectures (easier understanding)	5	7	4	10	***26***
· Involved active participation and drew a student's interest and concentration to the lecture, engaging and more pleasant.	1	1		1	***3***
· Not much help: some bits or not particularly helpful.	7	2	2	1	***13***
Total	14	13	10	17	54

Table 7-20 Benefits in lectures summarised

Visualisation itself in lectures was a useful means to support students' understanding with C++ programming. Moreover, it enhanced understanding through supporting the lecturer's verbal explanation. Thirdly, it engaged students in learning more actively. Table 7-21 displays students' responses classified independently for each category.

Learning supports with IMM C++ in lecture	MD	SD	SI	MI	Total
· Verbal explanation + Animation	1	3	2	4	10
· Visualisation	6	8	6	14	34
· Engaging & interesting	1	4	2	1	8
IMM C++ in lecture beneficial : 41 students (Table 7-18)	**7**	**11**	**8**	**16**	

Table 7-21 IMM C++ learning supports in lecture

Most responded to a visually presented lecture positively, but there were some, in particular MD group, who did not find having IMM C++ in lectures beneficial (see Section 7.4.7). Two students' comments on benefits of having it in lectures are:

> *B01S34:* That was *quite interesting* because you looked at things, you know, you *going along with what's shown and at the same time a lecturer's talking as well.* Say again, I think it more of help... learning as a bit ... they were *more enjoyable.* Quite enjoyable to go through examples... more enjoyable to learn. It was an additional help.
> *B01S35:* The animations and everything because *when you look at the picture, you have more, better understanding of how the thing works* – the pointers.

Excerpt 7-17 Examples: students' comments on the benefits of IMM C++ in lectures

C. IMM C++ in the learning environment: most liked or helpful

What students liked most and considered most beneficial about IMM C++ in the learning context are summarised in Table 7-22. Students were counted independently for each category. Most liked was having IMM C++ for independent learning as well as in lectures. Benefits from the integration was realised by students who used IMM C++ for learning. Most students who used T-IMM C++ and hyperlinks reported the benefits of detecting and correcting misconceptions; tasks and hyperlinks helped them identify and build knowledge where this was insufficient.

Most helpful things or liked from IMM C++	MD	SD	SI	MI	Total
· Independent learning support	6	8	6	13	33
· Integration and architecture of IMM C++		4	5	12	21
· T-IMM C++ helping test understanding	1	3	3	5	12
· Hyperlinks helping detect and correct misconception, and identify and build knowledge where insufficient.	2	3	2[17]	8	15
· Visualisation (visual examples)[18]	7	7	1	16	31
· Information layout (description and animation)	1	3		4	8
No of students with data (Table 7-18)	14	13	10	17	54

Table 7-22 IMM C++: most helpful and liked

As Table 7-19 and Table 7-20 present, there were some students, particularly MD group, who did not consider either having IMM C++ in lectures or for independent learning beneficial. What students found problematic and unsatisfactory with IMM C++ is discussed in next section.

7.4.7 Things unsatisfactory or problematic with IMM C++

Students expressed what they found problematic or unsatisfactory with IMM C++ in open ended questions and interviews. Some were related to IMM C++ itself in the learning environment: most were related to the delivery of it in lectures and insufficient

[17] One student who was not included here responded that hyperlinks in Tutorial IMM C++ had a potential for supporting learning.

[18] One each students from SD and MD groups answered "some".

information in R-IMM C++. Others were related to students' characteristics. Table 7-23 presents the summary of students' responses.

Things unsatisfactory or problematic	MD	SD	SI	MI	Total
Delivery in lectures					
· Too fast / Visual steps were too fast (visually confusing)[19]	3	4	1	2	**10**
· Difficult to concentrate for both animation and lecturer's explanation/ distracting rather than help	1		1		**2**
· Difficult to follow when missed a point or occasional problem with understanding		1	2	1	**4**
Insufficient information / examples for revision	2	4	2	3	**11**
Total	**6**	**9**	**6**	**6**	**27**

Table 7-23 Things students considered unsatisfactory or problematic

A. Delivery pace and visualisation in lectures

With or without using IMM courseware, it is difficult to accommodate each student's learning pace in lectures. However, students' experiences in this study suggested that IMM in lectures presented different aspects to be considered; visualisation together with verbal explanation can enhance teaching, but it can also cause cognitive overload when students do not have a sufficient time to integrate and assimilate text (verbal) and visual information together. Visualisation can convey a large quantity of information in a short time compared with text-based information. Students need a time to digest what is presented visually. A lecturer need give verbal description carefully not to overload students with too much information at the same time.

Visualisation, mainly animation, in IMM C++, supported learning in lectures with accompanying text information and with the lecturer's explanation. Unlike writing on a whiteboard, which requires time to write, the delivery pace with it relied on the lecturer. Some students considered that animations with text information were presented too fast

[19] Animations were considered a bit fast by some students even for independent learning. When a student had to keep replaying it, they became frustrated and discouraged to use it. Although only few cited this problem, control of animation was of an importance.

and a few considered visualisation distracting rather than enhancing the lecturer's verbal explanation. Students who used IMM C++ after lectures did not consider this as a problem[20], but ones who did not use it for revision found this problematic.

Students finding the delivery pace fast or having difficulties following lectures is not a unique problem in a lecture-based learning environment. With traditional methods, students struggle with their learning in lectures, which is one of the incentives to bring IMM into this learning context. However, some of the problems found in this study can be improved through slowing the delivery pace and simplifying animations. A well presented lecture with IMM courseware not only can help students understand what is delivered, but it also can show them how to use the courseware and encourage them to use it for learning.

B. Insufficient information or examples

IMM C++ was designed to help students build fundamental understanding with C++ programming with structured information representation and tasks. It did not contain extensive information of C++ or examples; this was designed but not implemented due to the time constraints.

Students responded to this in four different ways. Some students used it to grasp fundamental understanding of C++ and expanded their knowledge with other materials, which was the intended and recommended way. MI group approached IMM C++ this way. Second was students studying paper-based learning materials and occasionally using IMM C++ as a reference. SD group and some in SI group belonged to this and third types. Third and forth were students who wanted to use one type of learning materials. Third used it as the main learning material and expressed dissatisfaction because it did not provide all the information required for the subject matter. The fourth

[20] A comment – "Umm, during lectures, I can't expect the lecturer to go on my pace."

used paper-based learning materials only and considered IMM C++ inconvenient or not beneficial without trying it. The third group reported insufficient information in IMM C++ problematic, and some in the forth group were dissatisfied with the delivery pace in lectures or visually presented lectures. Many in MD group belonged to the fourth group.

C. Others

Others that students reported problematic or unsatisfactory were related to their characteristics. Each in SI, SD and MD groups reasoned their disfavour of IMM C++ with their preference of a human tutor rather than IMM courseware. A few others reasoned their unfamiliarity of learning with IMM as a cause. Two students in SD group considered more interactivity and user inputs to be added. Some of students' responses were contradictory; one is accessibility. Some disfavoured IMM C++ and gave 'inaccessibility' as a reason; it is not accessible everywhere unlike books. Others who favoured it gave 'accessibility' as a reason; it is accessible on the Internet, Intranet, at home and etc. This is one example of students' different perspectives on learning with IMM C++, and it reflects how the characteristics or perspectives of students affect their perceptions of and approaches to learning with it.

The primary aim of the interface and content design of IMM C++ was to make it easy to use. It was presented in a lecture, but still some students were reluctant to even try. Once students tried to use it for learning, most realised its benefits. But some students did not try it. Arranging an introductory session in the beginning could help students overcome some of their initial reluctance.

7.4.8 Characteristics of the four groups

The four groups experienced their learning with IMM C++ differently in the areas of: 1) their perceptions of learning with it, 2) their approaches to using it, 3) their learning outcomes and 4) their gains of learning support from it in the learning context.

Students' approaches to learning with IMM C++ were influenced by the characteristics of students: 1) prior experiences with IMM, 2) conceptions of learning, 3) preference of learning methods and 4) openness to a new approach. Their learning was also related to their approaches to learning: 'surface' or 'deep', and the learning environment in which students were engaged in learning: the assessment methods; the timetable; the distributions of IMM C++ and its integration with other paper-based materials. The characteristics of the four groups derived are presented in Appendix 10.

7.5 Summary

IMM C++ was developed based on the design and integration approach, presented in chapter 4, for a C++ programming module. It was integrated into the curriculum as a main teaching and learning material and used in lectures and tutorials.

Factors affecting students' approaches to the use of IMM C++ were identified from the data analysis: the assessment of a programming task in tutorials; the tutorial timetable; students' prior experiences; their approaches to learning. The variations in students' approaches to using IMM C++ for learning were found to be related to students' learning outcomes and the benefits of IMM C++ they realised in the learning context. These relationships are illustrated in Figure 7-10.

Some students benefited from having IMM C++ for both teaching and learning; their performances and perceptions were improved. Students who used it for their revision after lectures to achieve a better understanding of what was taught in lectures improved their performance most and realised the benefits of having it for both teaching and learning. Some of these students reported reflection as one of benefits. While they were using IMM C++ for learning, they could reflect on the lecturer's explanation.

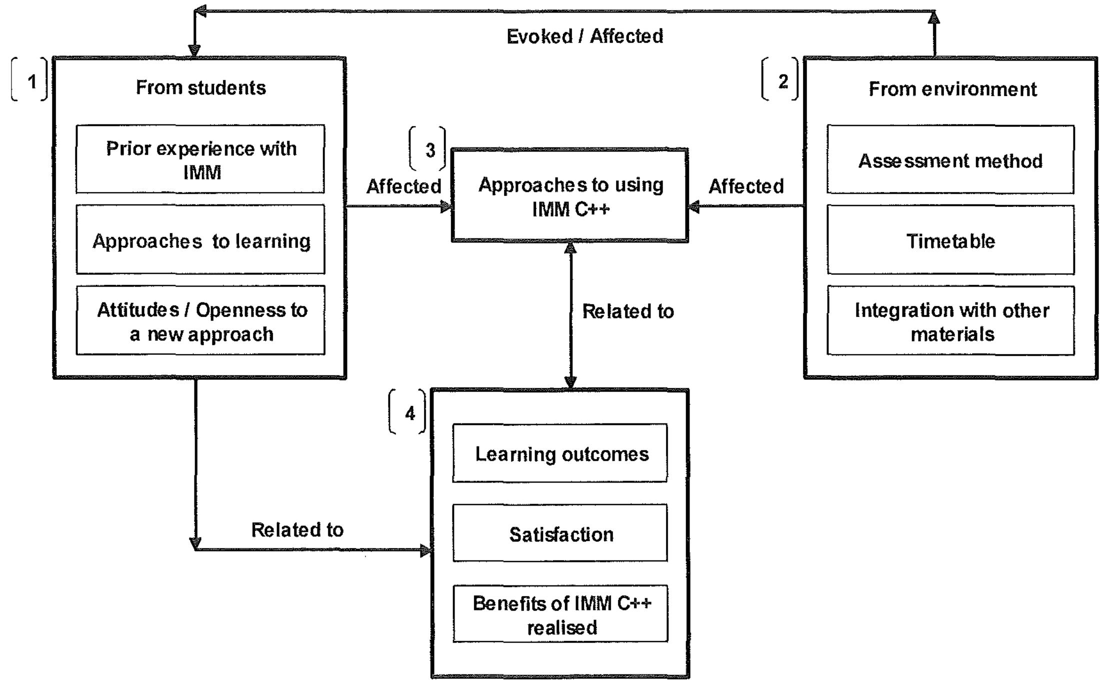


Figure 7-10 Student learning with IMM C++ in the learning context

This result illuminates an aspect of learning supports by IMM courseware when it is integrated for both teaching and learning. The approach in Chapter 4 emphasises facilitating student learning through using IMM courseware for teaching and learning (see Figure 4-4), and the results in this study provide evidence that when this integration approach is appropriately implemented, it can support student learning effectively.

The learning environment in this study affected student learning with IMM C++. In tutorials, students were required to use R-IMM C++ and do tasks in T-IMM C++. But many were discouraged to do them because they had a task to be assessed. This caused variations in students' use of both R-IMM C++ and T-IMM C++. Students who used T-IMM C++ reported benefits of identifying and correcting misconceptions, and testing and building knowledge where insufficient. It also enhanced students' retention and improved their performance. This suggests that the architecture of IMM C++ when integrated into lectures and tutorials is effective in facilitating learning.

In terms of the design features, most students considered visualisation beneficial both in lectures and in their own learning; it helped them understand C++ concepts easier and quicker. In addition, there were other benefits reported such as interactivity, control of learning and etc. The results in this study provide evidences that the design and integration is effective in facilitating student learning. One of the most significant results from case study 2 was that teaching and learning with IMM C++ supported weak students in performance and perception.

This study also enlightened certain aspects of the teaching and learning process to be considered: contextual and personal aspects that affect student learning. Key contextual factors found to affect student learning in this study were assessment methods and timetable. Others were the distribution of IMM courseware and integration of it with other learning materials. In terms of personal aspects, students' prior experiences and their attitudes affect their approaches to learning and to using IMM courseware. A learning environment needs be designed to encourage students to use IMM courseware for learning.

Another aspect to be improved is the content design of IMM courseware. Some students expressed dissatisfaction with the amount of information in IMM C++. Implementing hyperlinks to other learning materials in the integration approach could solve this problem. Further investigation is required to derive a better solution. The same applies to the design and delivery of animations; most considered them beneficial, but some did not in lectures.

The findings in IMM C++ supporting interactions between students and teaching staff, and the benefits of IMM C++ in the context for lecturers and departments are not discussed in this Chapter. These will be discussed together with the results from case study 3 in Chapter 8.

CHAPTER 8 CASE STUDY 3: TEACHING AND LEARNING WITH IMM FROM LECTURER'S PERSPECTIVE

Case studies 1 and 2, reported in the previous two chapters, investigated student learning with IMM in classroom environments. The primary aim was to evaluate the effectiveness of the integration approach, proposed in Chapter 4, for learning through investigating students' learning with IMM. A difference between the studies was that whereas case study 1 focused on group learning effects facilitated by IMM courseware, case study 2 focused on individual student learning with IMM courseware. In addition, case study 1 evaluated the learning effects between the three different hyperlinks treatments in T-IMM, and case study 2 investigated only the dynamic-hyperlink treatment.

The data from case study 1 revealed that the use of IMM courseware for teaching and learning improved student learning with the subject matters: in both performance and perceptions. It had also encouraged and supported independent learning. As for hyperlinks, the dynamic-hyperlink treatment was found to be most effective for student learning in case study 1.[21] Based on the findings from case study 1, case study 2 investigated individual student learning experience with IMM courseware. The data from this study revealed that students, who had used R-IMM after lectures for revision and who had used T-IMM, benefited most; their performance and perceptions of learning C++ programming improved significantly. Case study 2 also revealed variations in students' approaches to using IMM C++ for learning and factors affected their approaches.

This chapter reports the third case study that investigated teaching and learning of programming with IMM courseware. This study was conducted at Brunel University

[21] If the IMM courseware had not been used in lectures as well as in tutorials, the results may differ between the static-hyperlink and dynamic-hyperlink treatments.

from September 2001 until January 2002. IMM courseware was integrated into the Object-Oriented Software Design (OOSD) and Object-Oriented Programming Workshop (OOPW) modules. Compared with two previous studies, this study differed in two ways. In the previous studies, IMM courseware had been developed for the programming modules investigated, and the module leader, *Lecturer N* and *Lecturer B*, had collaborated in the development of the courseware. The content had been tailored as the module leaders had considered suitable for the modules. Unlike the two previous studies, in this study the IMM courseware (IMM OO) developed for object-oriented design at Napier University (case study 1), was used. The other difference was that the majority of the students, who registered the OOSD and OOPW modules, had been the participants of case study 2. The majority had experienced using IMM courseware for both teaching and learning. The data from case study 2 revealed that students' prior experience with IMM affected their perceptions of and approaches to learning with IMM courseware. It was interesting to investigate how these students' experience with IMM C++ would affect their perceptions of and approaches to learning with IMM OO.

The focus of case studies 1 and 2 was to investigate the learning support of the integration approach from students' perspective. To investigate the benefits of the approach for teaching as well as learning, this study focused on investigating the teaching and learning processes with IMM courseware from the lecturer's perspective. In addition, this study further explored the learning effects of visualisation and hyperlinks, and factors affecting the teaching and learning processes with IMM.

8.1. Aims of the study

This study aimed;

- to investigate the effects of the integration approach, presented in Chapter 4, from the lecturer's perspective;

- to explore the learning effects of visualisation and hyperlinks;.
- to explore personal and situational factors that affect teaching and learning processes with IMM courseware.

8.2. Methods

8.3.1. Participants

The participants were 82 second year students who registered the Object-Oriented Software Design (OOSD) and Object-Oriented Programming Workshop (OOPW) modules. Among them, 55 students had used IMM C++ from their studies with the Pg & SD 2 module in the previous semester (Section 7.2.1). The rest, 27 students, were either direct-entry to second year or elective students; most did not have background knowledge of C++ programming.

The majority of students in these two modules were from three different courses as follows:

- Computer System Engineering (CSE): 38 students;
- Electronic & Micro-electrical Engineering (EME): 9 students;
- Internet Engineering (IE): 23 students;
- Other courses: 12 students.

8.3.2. Object-Oriented Design & Programming Workshop modules description

In the 2001/2002, the department of Electronic & Computer Engineering at Brunel University offered two co-requisite modules to second year students: the Object-Oriented Software Design (OOSD) and Object-Oriented Programming Workshop (OOPW). The OOSD module aimed to teach object-oriented analysis and design with UML, and the OOPW module was designed to teach implementation of object-oriented programming with either C++ or Java.

The timetable of the two modules was as follows:

- OOSD module: two 1 hour lectures and one 1 hour seminar per week;
- OOPW: one 3 hour tutorial per two weeks.

These two modules consisted of the same curriculum activities as the Pg & SD 2 module in the previous semester (Section 7.2.3). However, there was a difference in teaching staff. Whereas the Pg & SD 2 module had been taught by team teaching, these modules were delivered by one lecturer, *Lecturer B*, and one demonstrator. This affected positively in facilitating student learning with IMM courseware as *Lecturer B* could create a learning environment which encouraged students to use the IMM courseware.

8.3.3. IMM courseware (IMM OO) integration into the curriculum

As mentioned in Section 8.3.1, the majority of the students were from three different courses and they were expected to use either C++ or Java. This is summarised as follows:

- CSE / EME / Others (58 students): C++ with C++Builder
- IE / Others (24 students) : Java with JBuilder

To assist teaching in lectures and to support learning with the two modules, *Lecturer B* integrated IMM courseware (IMM OO), developed for the SD 1B module at Napier University (Section 4.5.2), into the curriculum. Prior to the integration, she assessed the courseware to determine its suitability for the modules. Initially it was planned to further develop IMM OO so that it could support student learning for the whole semester. However, due to the time constraints, IMM OO was used without any additional development. R-IMM OO was used in lectures, and T-IMM OO was used in tutorials. Course materials and tools used are summarised in Table 8-1.

Component	Week	Materials	Tools
Lecture	**Week 1-7**	· R-IMM OO · Writing and drawing on a whiteboard · Handouts	
	Week 8-15	· PowerPoint slides with animations · Writing and drawing on a whiteboard · Handouts	
Tutorial	**Week 1-7**	· Tutorial IMM OO · Paper-based programming tasks	C++Builder/JBuilder
	Week 8-15	· Paper-based programming tasks	
Workshop	Week 1-15	· Practical design work	· Pen & paper
Learning materials	Week 1-15	· IMM OO · IMM C++ from the Pg & SD 2 module · PowerPoint materials for C++ / Java · Online materials for C++ and Java · Text books and handouts	

Table 8-1 Materials and tools used for the OOSD and OOPW modules

As described in Table 8-1, for the first 7 weeks, IMM OO was used in lectures and from week 8 PowerPoint materials. The PowerPoint materials had been used for the OOP module in the previous year with which the pilot study had conducted (Section 5.3).

Facilitating students' use of T-IMM OO in tutorials

In case study 1, 5 tutors had been assigned for the SD 1B module tutorials (Section 6.3.3). The data from this study revealed that a lack of communication between the teaching staff had negatively affected student learning with IMM (Section 6.6.4). To avoid this problem, in case study 2 with the Pg & SD 2 module, which also had been delivered by team teaching, the teaching staff had been contacted in advance and asked to try IMM C++. After evaluating IMM C++, they had returned feedback to *Lecturer B*. However, students' responses during interviews suggested that other teaching staff except *Lecturer B* had not actively encouraged students to try to use T-IMM C++ in tutorials. Some students had even been unaware of T-IMM C++.

To improve the situation in this study:

- in lectures *Lecturer B* continuously informed students to use T-IMM OO;
- in the first tutorial, *Lecturer B* requested students to do the tasks in T-IMM OO;
- the demonstrator was informed of the courseware in advance and asked to encourage students to use it.

Independent learning support

To support students' independent learning, IMM OO, IMM C++ and PowerPoint slides were installed on both the university Intranet and Internet.

8.3.4. Research methods

This study aimed to explore the teaching and learning experience with IMM courseware in-depth, and to investigate cognitive effects of visualisation and hyperlinks. A mixture of qualitative and quantitative methods was used, but the emphasis was to collect rich qualitative data from interviews, observations, and open questions. As for questionnaires, more questions were added to explore student learning experience in case studies 2 and 3.

E. Interviews

Interviews with students were conducted to investigate student learning experience with IMM courseware. Interviews were scheduled at two different phases: the first in week 4 and week 5, and the other in week 13. Thirty seven students were interviewed in week 4 and 5, and 11 were interviewed in week 13. The aims were, first of all, to investigate how students used IMM OO and perceived their learning with it. Secondly, they were aimed to obtain students' background information such as whether they had taken the Pg & SD 2 module. Thirdly, they were to explore whether the students including the new students used IMM C++ for independent learning. Among the interviewees in week

4 and 5, 27 had taken the Pg & SD 2 module in the previous semester and 10 were new. Among the 11 students who were interviewed in week 13, 8 had taken the Pg & SD 2 module and 3 were new.

As for the interviews with the teaching staff, formal interviews with *Lecturer B* were conducted at 3 different stages: the first in the beginning, next in week 6, and the last in week 14. The demonstrator was interviewed in week 5. Additionally, many informal conversations took place between *Lecturer B*, the demonstrator and the author. All interviews, both with students and the teaching staff, were transcribed by the author.[22]

F. Questionnaires

Two questionnaires, included in Appendix 11 and 12, were conducted to ascertain student learning experience with IMM courseware during case study 2 and this study. The first questionnaire survey was conducted at the end of week 3. *Lecturer B* had been using IMM OO in lectures for three weeks (6 lectures). Fifty one students participated in the first questionnaire. Forty four students identified themselves, and 7 did not.

The aim of the first questionnaire was to investigate students' perceptions of their learning with IMM OO and benefits of IMM OO in the learning environment. With the students' responses, it was planned to compare their perceptions of learning with IMM C++ in the previous semester. From analysing the data from case study 2, students' prior experience with IMM was identified as a factor that had affected students' learning with IMM C++ (Section 7.4.2). It was interesting to explore whether and how their learning experience with IMM C++ had affected their perceptions of and approaches to learning with IMM OO in this study.

[22] Data transcribed had grammatical errors in various places, and they were not corrected to keep the original expressions of the students. Some could be transcription errors made by the author.

Analysing the questionnaire data revealed that among the 51 participants, 35 students had taken the Pg & SD module in the previous semester. The other, 15 students did not take the module, and one was unclear. The second questionnaire was answered in week 13. Only a limited number of students responded to it because lectures and tutorials were close to the end and a reduced number of students attended them. In addition, most students were concentrating on their final assignment.

G. Tracking

Like the previous studies, tracking was programmed to record how students used IMM C++ and IMM OO. In this study, tracking files were analysed only to determine the frequency of students' use of IMM C++ and IMM OO for independent learning.

H. Observation

Observations were conducted in lectures and tutorials. The aim was to observe students' interactions with IMM OO, peer students and teaching staff.

8.4. Data collected and data analysis

Data collected

The data collected from this study is summarised in Table 8-2.

C++ Pg & SD 2 in previous semester	Questionnaire 1[23]	Questionnaire 2	Interviews in week 4 and 5	Interviews in week 13
Yes	35	6	27	8
No	15	2	10	3
Not identified	1			
Total	51	8	37	11

Table 8-2 Data collected in case study 3

As displayed in Table 8-2, students were divided between who had used IMM C++ with the Pg & SD 2 module and who were new to the modules.

[23] Among 35 students, 17students were identified as having participated in the first questionnaire and 9 did the second questionnaire in case study 2. Their responses from the three questionnaires were cross-examined together with their interview data.

Data analysis

This study continued from case study 2. Prior to data analysis, an Excel file and an SPSS file were created to store all students' data from both case studies: interviews, questionnaires, tracking, exam marks from three semesters (2 from first year) and observations. Each student record contained their data from all research methods they had participated in both studies. Qualitative data from interviews, open questions and observations were carefully classified into several categories for the research themes, enumerated and recorded.

In terms of analysing data, at first, a theme was identified and defined. Next, several categories were created under the theme, and students were classified accordingly. Their responses were carefully examined in each category. This approach was used to determine whether and how the integration of IMM courseware in the context had supported or influenced student learning experience. Much effort was put into the analysis and interpretation of the data to report meaningful results, but due to the nature of this empirical study and the author's limited knowledge and experience, it was difficult to present a clear account of how effectively the integration approach facilitated student learning of programming.

8.5. Results: facilitating the 'iterative' teaching and learning processes

This section presents the results and findings from analysing the data collected from this study.

8.5.1. Student learning experience with IMM OO

The data from case studies 1 and 2 suggested that the students who perceived their understanding of the subject matter good were likely to consider it easy (Section 6.6.1, and Section 7.4.1), or vice versa. Also, the data revealed that the students, who rated their enjoyment of studying the subject matter high, perceived the subject matter easy or their understanding of it good, or vice versa.

A. Perceptions of C++ programming and Object-oriented design

The data in case study 2 showed a positive change in students' perceptions of C++ programming, between before and after they had started the Pg & SD 2 module with IMM C++ (Figure 7-1 and Figure 7-2). The students had studied C++ programming in semester 1 of 2000/2001 already, and the change could be a result of their familiarity with the subject matter. To investigate whether the positive change in students' perceptions of C++ programming was as a result of integrating IMM C++ for teaching and learning, a question about 'students perceptions of C++ programming' was asked at the end of week 3. The results are displayed in Figure 8-1.

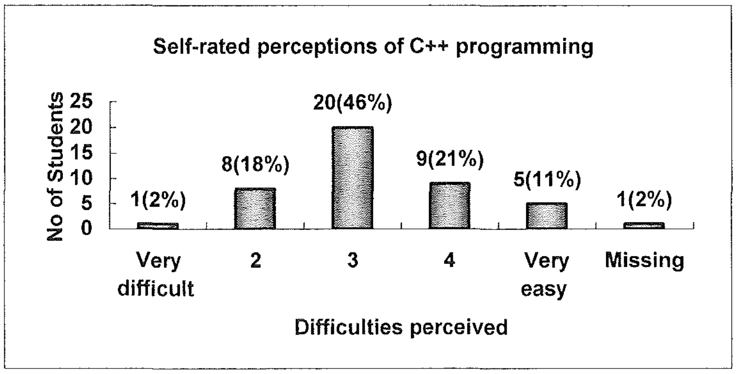


Figure 8-1 Students' self-rated perceptions of C++ programming (students identified = 44)

As presented in Figure 8-1, 20% (9/44) of the students considered C++ programming difficult, but 32% (14/44) considered it easy. The results presented include the new students' data. To investigate the perception change in the students, who had taken the Pg & SD module in case study 2, their responses were examined separately. Little difference was found compared with the results including the new students; 23% (6/26) considered C++ programming difficult and 31% (8/26) perceived it easy. It was interesting to find that the degree of difficulty/ease the new students perceived of C++

programming was similar, a little more positive, to the students who had taken two programming modules in their first year.

To explore whether students' perceptions of C++ programming changed between the previous semester and this semester, their responses were compared. The results showed no significant change although the result was slightly more positive in this semester. At the end of the previous semester, 28% (12/44) of the students had rated C++ programming to be difficult and 23% (10) reported it to be easy. These results were compared with the change in students' perceptions of C++ programming between before and after using IMM C++ for 3 weeks with the Pg & SD 2 module in the previous semester (Figure 7-1). Before students taking the Pg & SD 2 module, 64% had perceived C++ programming difficult and only 16% had considered it easy. The results from the comparison suggests that the positive change in students' perceptions of C++ programming was more as a result of integrating IMM C++ in the context than led by their familiarity with the subject matter.

Students' perceptions of object-oriented design

In addition to C++ programming, students' perceptions of object-oriented concepts were ascertained. The results are presented in Figure 8-2.

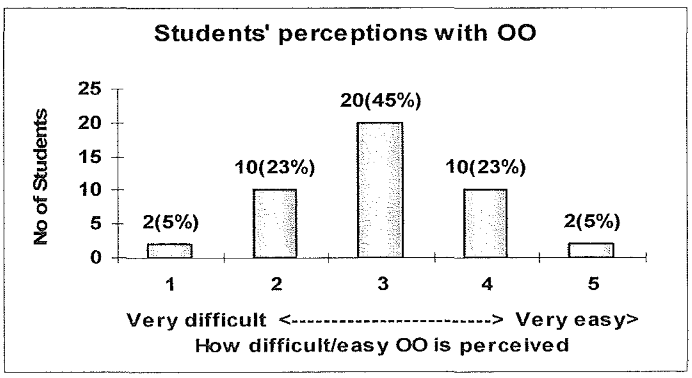


Figure 8-2 Students' perceptions with OO concepts

As Figure 8-2 shows, 28% (12/44) rated OO concepts difficult and 28% (12/44) perceived it easy. The students were new to the subject matter, but their responses were similar to their self-rated perceptions of C++ programming. Furthermore, the new students' perceptions of C++ programming were similar to these data. These results confirm that the positive change in students' perceptions of C++ programming had been a result of using IMM C++ in the previous semester, and students' perceptions of object-oriented design were positively affected by the use of IMM OO.

B. Students' self-rated understanding with OOSD

At the end of week 3, students were asked about their understanding of object-oriented design, and the results are illustrated in Figure 8-3.

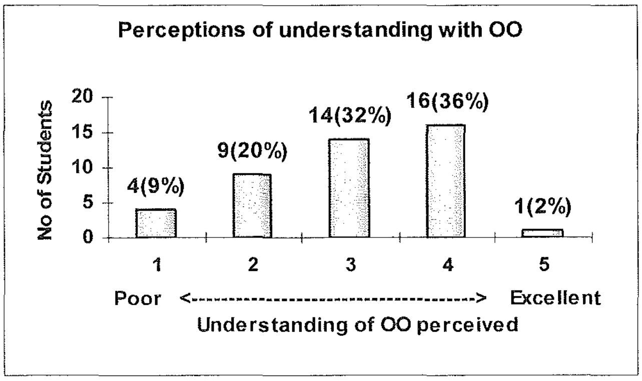
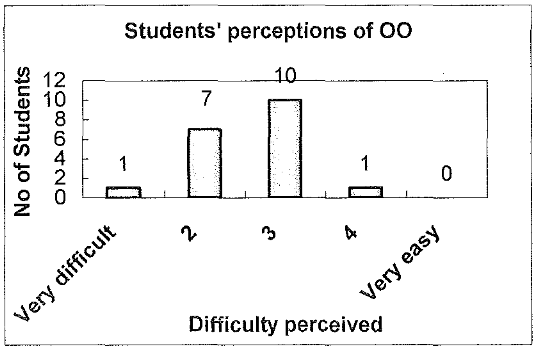
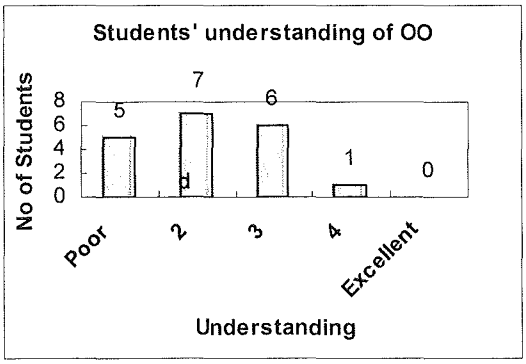


Figure 8-3 Students' self-rated understanding of OO concepts

As presented in Figure 8-3, 29% (13/44) of the students perceived their understanding of object-oriented concepts insufficient (close to poor), and 38% (17/44) of the students rated their understanding to be good. Students' responses to this question were slightly more positive than their perceptions of the subject matter. To determine how much the use of IMM courseware for teaching and learning had improved student learning, the students' perceptions of and self-rated understanding with object-oriented concepts were compared with the previous year students, who had participated in the pilot study (Section 5.3). The previous students' responses are displayed in Figure 8-4.



a) How easy to understand OO concepts



b) Students' understanding of OO concepts

Figure 8-4 Previous year students' perceptions of OO and their self-reported understanding of it

As displayed in Figure 8-4, the majority of the students (63%) had rated their understanding insufficient (close to poor). Also, 40% (8/19) of the students had considered object-oriented concepts difficult and only 1 student had perceived it easy. As these questions had been asked in week 10 of the previous year, their responses could not be considered to be led by their unfamiliarity of the subject matter. In addition, the module was delivered by the same teaching staff, *Lecturer B*. Considering the circumstances, the results are indicative that the integrating of IMM OO for teaching and learning improved student learning experience.

C. Enjoyment of OOSD and OOPW modules

Students' responses of how much they enjoyed the modules were more positive than their responses for C++ programming with the Pg & SD 2 module (Figure 7-3); they were similar to the students' responses for object-oriented design in case study 1 (Figure 6-12).[24]

[24] The results in case study 1 were slightly more positive. Only 15% of students (59) rated their enjoyment to 1 (1 student) or 2 (8 students), and 31 (53%) rated it to 4 or 5.

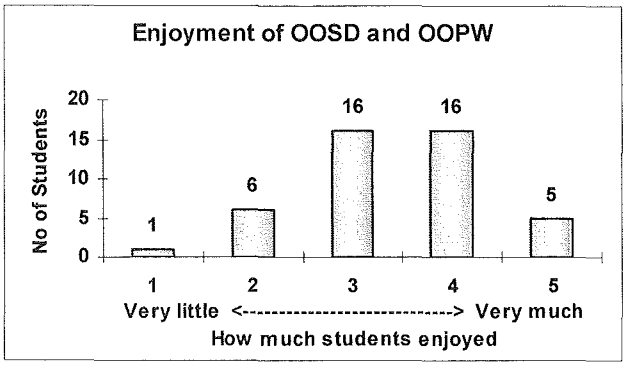


Figure 8-5 Students' enjoyment of OOSD and OOPW

As Figure 8-5 shows, 48% (21/44) of students rated their enjoyment of the modules to 4 or 5 on 5 point semantic deferential scale, and 16% (7/44) graded their enjoyment to 1 or 2. Among the 7 students, 3 had not taken the Pg & SD 2 module, and 1 had an extensive programming work background. The data from students' interviews revealed that the majority of students' enjoyment in learning object-oriented design was increased by the use of IMM OO. One student's comment during interviews is displayed below.

> *SH*: How did you consider IMM materials from your modules?
> *B02S14*: Yes, I found them a lot easy and clever to understand.
> *SH:* Have you used them for your own learning?
> *B02S14*: Yes. I use them a lot. Because I can't download the materials onto my computer. So, I can't use them in my room. But, I use them a lot at university. It's *funny*. It's *much easier for me* anyway. So, I *really enjoy using them.*
> *SH:* Which one do you like to use for learning between multimedia and paper-based materials?
> *B02S14*: ... I like both actually. But I think on many occasions, I'd rather use multimedia materials because they are clever. You can always use what you want to use. You can access them at any time. That is one of main points. You don't have to have a lecturer or tutor and it's clever. Because you know that you would get your answers for what you do, it's easier to understand more. Because I see examples in front of me when I want them.

Excerpt 8-1 Examples of students' comments about learning with IMM

B02S14's comment, echoed by many others, suggests that he enjoyed using IMM OO, and used it frequently for learning at university.

8.5.2. Use of T-IMM OO and learning effects of hyperlinks realised

Students' use of T-IMM OO in tutorials

As described in Section 8.3.3, many students in the previous semester did not use T-IMM C++ in tutorials or for their learning. A reason identified was that the students had not been introduced to T-IMM C++ like R-IMM C++ which had been by its use in lectures. Because of their unfamiliarity to T-IMM C++, the students had been disinclined to try it first time. Some students commented that they had not used it because their tutors had not *forced* them to try it. In worse cases, some were unaware of T-IMM C++. *Lecturer B* explained the situation with:

> *TK*: With the lecture IMM [R-IMM C++], students experienced it from lectures and were aware of its benefits for learning, so they used it for learning. However, students did not see how the tutorial IMM [T-IMM C++] was used and were unaware of its benefits, so they did not want to try it.

Excerpt 8-2 *Lecturer B*'s description of why students did not use T-IMM C++ in previous semester

To remedy the situation, *Lecturer B* requested, nearly forced, the students to try T-IMM OO in the first tutorial. Initially some students showed reluctance to try T-IMM OO. The following is *Lecturer B*'s description of students' initial attitudes toward using T-IMM and what she had to do in order to facilitate students to use it.

> *TK*: They accepted the concept of using IMM once they have used it for a while. But at the beginning, I needed to force them to start to use it. Because *almost none of them were willing to start to use tutorial materials [T-IMM].* The lecture materials[R-IMM], they have seen them during lectures, so they used them because they have been familiar with them already and they felt more confident when they've been using it. But *they've never seen tutorial materials before.* They're using lecture IMM materials as a reference in most cases. *After requesting to use the tutorial IMM material in the lab, it changed the situation.* I have started to have some more positive feedback from students. *They liked it.* They *asked me to develop more questions in tutorial IMM to learn more concepts.*

Excerpt 8-3 *Lecturer B*'s description of positive change in students' attitudes toward T-IMM

As *Lecturer B*'s comment suggests, once students tried the questions and tasks in T-IMM OO, they became interested in using it for learning. Students' responses during interviews in October became very positive in terms of their learning with T-IMM. The students, who had used T-IMM OO, seemed much interested in learning with it. This may be related to the increased number of the students who had used T-IMM C++ for independent learning in October, as will be reported in Section 8.5.5. As mentioned above, many students had not used T-IMM C++ in the previous semester. However, when many of these students tried IMM OO in tutorials or for learning, they realised its benefits for learning. Furthermore, they seemed to enjoy the learning experience with it. The following is one of many comments made by students about how they started to use IMM OO.

> *SH*: Did you use the IMM materials for learning in the previous semester?
> *B01S1:* To be honest, no.
> *SH:* Why didn't you use them?
> *B01S1:* I mean, we just did it, did some in the class, and that was it. Basically, I just went to the lectures and I read books. I didn't really look at the .....[IMM materials] because they didn't really *force* us to do it. But this year after they were like ... *forcing us, so we can see what it is about or isn't, so we can get more interested in by using them.*
> *SH:* So, last semester you were not interested in using the multimedia [he cut it in]
> *B01S1:* No, because they didn't really force us, but this year they showed us, they ... for labs they took us and forced us just to use it, so....*Now I realise what is happening.* Before I didn't know what's happening.

Excerpt 8-4 One of students' comments on inactive use of IMM and reasons behind

The data from case study 1 (Table 6-10) revealed that students had enjoyed T-IMM OO in tutorials more than R-IMM OO in lectures. They also had considered it more beneficial than R-IMM OO for learning. The interview data from this study also revealed a positive change in students' perceptions and approaches to using T-IMM OO; after the first try, they became to use T-IMM OO actively.

Learning effects of hyperlinks in the context (problem-solving context)

During the observations in weeks 4 and 5 students' active use of T-IMM OO was observed. To investigate how students perceived hyperlinks in T-IMM, interview data with students was analysed. Among the interviewees (37) in weeks 4 and 5, 29 students' use or not use of T-IMM OO in tutorials or for learning were identified. All, but one, had used it, and they considered it helpful for learning. Among these students, 17 had used hyperlinks in T-IMM OO. One student responded negatively and explained that the hyperlinks in T-IMM had disoriented him. However, the other 16 students perceived hyperlinks helpful for their learning. Some of the students' comments are listed below.

> *B02S1:* Basically it helps *revision*, yes. I like it.
> *B02S2:* Umm, this is actually the first time that I'm actually using these ones because I didn't use it last year. Now we are doing questions for *revision*. It gives you good questions. It gives you a chance to answer. And pressing the answer button, this, it will check answers for you. And will say whether I am right or wrong, and it also displays the answer to the question. So, that's really good.
> *SH:* Does it help you understand the concepts?
> *B02S3:* Yes, it is good for learning. Yes, it does. Answering concepts.
> *SH:* Which part of the multimedia materials do you find most beneficial?
> *B02S3:* Questions and answers, yes, I find questions and answers very good. The examples are, they are not bad examples, but *questions and answers really helped* because it demonstrates and so you know, it shows and so.

Excerpt 8-5 Examples: students' comments on benefits of T-IMM OO

Many other students gave similar comments; many considered doing the tasks helped them revise what they had learnt in lectures. However, the students, who had used hyperlinks in the material, considered using T-IMM OO more beneficial than doing tasks only. Two of students' comments are displayed below.

> *B02S4:* Because by doing this multimedia, we can ... it's like we're testing ourselves, we can find out how much we know about ... the book [IMM OO] that we did in the lectures, and *we can test ourselves. If we make a mistake,*

then we can go back to it and we can find out why we made that mistake and ...Yes, you *can correct your mistakes, you can understand what's happening in the lectures as well*, you can understand what's right on side. It helps you in the exams as well if you understand what's happening.

B02S5: Yes, help me understand. Because if you answer a question, you *look up the answer and what it means. If you find out where you went wrong, and then you can improve on that.*

SH: How about using IMM in the lecture?

B02S5: They are fine as well. But, this is more, better I mean.

... Together even better, you understand more when you get lectures like ... they teach you and this is like they *test how much you know*, ... like what you are going through while in the lecture.

Excerpt 8-6 Examples: students' comments on learning support from tasks and hyperlinks

Many students, who had used hyperlinks, described the benefits of them in similar ways. The data from interviews, particularly January ones, revealed that when students continued to use T-IMM OO and hyperlinks, they realised that the hyperlinks helped them more than revising what they had learnt in lectures. These students became active users of T-IMM OO. A part of an interview in January 2002 is displayed below.

SH: How did you consider IMM OO and PowerPoint materials you used for these modules?

B02S6: I liked both of them [IMM OO & PowerPoint materials], both of them, they came handy for ... like for use case diagrams or UML, I feel the IMM ones better, but for the rest of the course where she used PowerPoint ones, that was ok as well.

SH: Why did you consider IMM was better for UML?

B02S6: Because ... UML, because UML needs a lot of practical illustrations for us to understand, which the IMM did for us.

SH: Have you used IMM OO for learning?

B02S6: Yes, I have used them.

SH: Both tutorial IMM and lecture IMM?

B02S6: Yes. I used them.

SH: How did you consider them for learning?

B02S6: Yes, *quite useful*, *very very useful.*

SH: In which aspect?

B02S6: Umm, like *when I answer a question wrong, it tells me the correct answer.* It helps me understand very well. *When it links to the lecture notes [R-*

IMM OO] instead of having to search the lecture notes, it makes me know my weak points and where I need to study more.

SH: Did you consider them helpful?

B02S6: Yes because if you don't understand something, it will give you. If you do questions in the tutorial (IMM), it will give you the answers. *If you don't understand it, it will give you links. You can look up and understand it further. So, you will pretty well understand.*

SH: How do you consider using them in tutorials?

B02S6: Very good. *Because you can easily do just practical things. You can sort of putting you through practising what you learnt in lectures. Because it shows you understand it or not, so you know early on.*

Excerpt 8-7 Examples: a student's comment on T-IMM and hyperlinks supporting learning

Like B02S6, many students commented on how helpful hyperlinks were for their learning. As will be discussed in the next section, most students considered visualisation in IMM OO beneficial both in lectures and for learning because it was used in lectures. But for hyperlinks or tasks in T-IMM OO, students realised the benefits only after they had used T-IMM OO. The students, who had used hyperlinks in T-IMM OO, became interested in learning with IMM OO. The part of an interview displayed below confirms this.

SH: How did you consider IMM materials for C++?

B02S7: Yes very beneficial. Umm it wasn't just C++... well, C++ addresses and the memories were very useful.

SH: Pointers?

B02S7: Yes, pointers and data structure, and that sort of things.

SH: Do you mean visualisation [he cut it]

B02S7: Yes, the visualisation made it *much* easier to understand.

SH: Have you used IMM materials for OO?

B02S7: Yes.

SH: How do you consider them?

B02S7: Brilliant multimedia materials, you know, because you can follow through your own pace and ask questions when you go along. Very useful.

SH: So,[he cut it]

B02S7: And the links, sorry, the links to other topics as well when you get questions wrong, that's quite useful.

SH: In which way?

B02S7: I will say, when you do answer questions on the ....[T-IMM OO], when you answer some questions, if you don't know the answer, you can just, *you take hyperlink to an area which is going to help. So, if you don't understand something ... you can jump straight to the part of the subject.*

SH: Does it correct your mistake or misconception?

B02S7: Yes.

Excerpt 8-8 Example: students' comments about learning supports of visualisation and hyperlinks

B02S7 considered visualisation in IMM C++ helpful, but with IMM OO he emphasised benefits from tasks and hyperlinks. Like many other students he may not have used T-IMM C++ in the previous semester. The increased number of students, who had used T-IMM C++ in October, could be indicative of how much using T-IMM OO encouraged active learning (see Section 8.5.5).

8.5.3. IMM OO in lectures and learning effects of visualisation

Use of IMM OO in lectures and for learning

"A picture is worth a thousand words." This was what one of the students quoted to describe the benefits of visualisation for his or her learning. At the end of week 3, in order to ascertain how students perceived IMM OO in lectures, a question about 'IMM OO in lectures can improve understanding' was asked. The results are displayed in Figure 8-6.

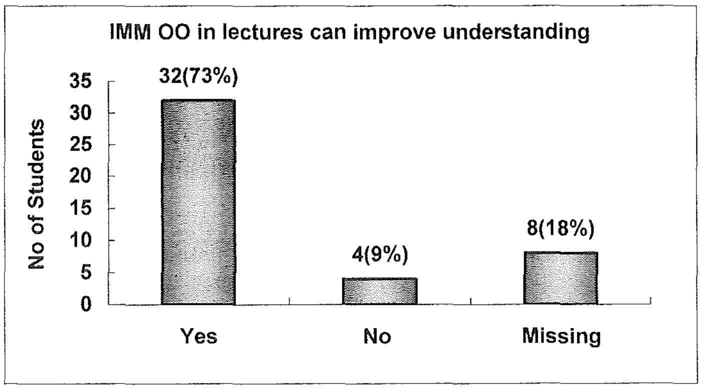


Figure 8-6 Students' responses for 'IMM OO in lectures can improve understanding'

As displayed in Figure 8-6, 73% (32/44) perceived that IMM OO in lectures could improve their understanding. Four students responded negatively and 8 did not answer the question. To identify who responded negatively, students' interviews data and their performance in the previous semester were examined. The analysis revealed that 4 advanced students, 3 from the Pg & SD 2 module and 1 new, responded negatively. They explained in interviews that they were advanced students and IMM OO was not much help for them as they already had a good understanding of object-oriented concepts.

Among the students who responded 'missing', 2 students were identified as 'new' students. As these students did not participate in interviews, reasons could not be identified. However, it may be caused by their unfamiliarity of using IMM in lectures. The data from case study 2 revealed that students' prior experience with IMM had affected their perceptions of and the initial use of IMM C++ (Section 7.4.2). Only 2 new students had a prior experience with IMM, one of whom was one of the students who responded negatively identifying himself as an advanced student.

To explore how IMM OO in lectures improved student learning with object-oriented concepts, the student interview data was analysed. The data from case studies 1 and 2 already pointed out that visualisation in IMM courseware have two benefits: one assisting teaching in lectures and the other supporting learning after the lecture. The students in this study also identified the two most beneficial from their learning with IMM OO.

Learning effects of visualisation of object-oriented concepts

The data from the preliminary study, reported in Chapter 3, had informed the potential of visualisation for the subject matter. The results from case studies 1 and 2 enlightened the benefits of visualisation for programming domains – both in lectures and for independent learning. How much students considered visualisation in lectures helpful for learning was asked in week 4. The results are displayed in

Figure 8-7.

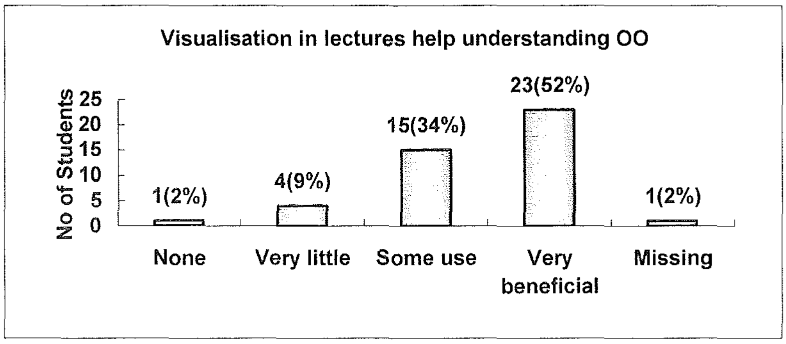


Figure 8-7 Visualisation in lectures assisting understanding OO

As illustrated in

Figure 8-7, 86% (38/44) of the students perceived visualisation in lectures beneficial for their understanding of object-oriented concepts. Only 5 students viewed it little help. In addition to the 38 students, 12 more students, identified from the analysis of interview data, reported visualisation in lectures to be beneficial.[25] Some of the comments illustrating the benefits of visualisation in lectures are presented below.

> *B02S8*: Umm, actually I liked the way they were given. With the IMM, the good thing is like *...you can see what's going on* ... Dr Kalganova used to give us some ... drawings, yes animations, and that helped us understand *concepts of the objects and classes and how they can be related*, things like that.
> *B02S9*: Yes, it's useful because we *see the effects of what she's saying*. Receive images, the function of, the definition of what she's saying.
> *B02S10*: Umm, the visualisation helps me when she is doing her actual lectures because it *shows her explanations broken down*, in the actual steps, which is really good. ... It does basically do step by step thing, but it's better. It did show and it does make it easier for you, which is, I personally think anyway that it is very useful.

[25] In October 2001 and January 2002 interviews, 39 different students were interviewed. Thirty seven students in October and 11 students in January were interviewed. Among them 9 were interviewed twice. Thirty five responded that visualisation with IMM OO in lectures helped their understanding, and 2 responded negatively.

> *B02S11*: Yes, especially the one prepared with the multimedia parts for C++ that I found helpful, yes.
> *SH:* In which way was it helpful?
> *B02S11*: Ah, the lecture given in the multimedia was *much more clear and easy to follow*. ... Because of animation.
> *B02S12:* Makes things prettier as well. *More interesting* presentations. Aids in *livening up a boring audience – increase understanding.*

Excerpt 8-9 Examples: students' comments on learning support of visualisation in lectures

Most students' perceptions of visualisation in lectures were positive. As B01S12's comment suggests that some students enjoyed having animations in lectures as well as considered it helpful for learning. Although most considered visualisation in lectures helpful, two students replied that it was not.

> *B02S12*: During lectures, it was *too fast to really appreciate what was there* and not always comprehensible. So, not too much. It was good to use afterward, but I didn't find it totally useful always.
> *B02S13*: IMM in lectures is not effective. *Cannot read and look at animations at the same time.* IMM for learning, it's definitely effective. Can play animation as many as want, read information and go through one's own pace.

Excerpt 8-10 Examples: students' comments about visualisation not helping in lectures

These comments were from January interviews. B01S13 had used IMM C++ in the previous semester and had made the same comment about animation not helping in lectures. IMM OO has much simpler animations unlike IMM C++ which had more complex animations. The analysis of students' comments suggested for some students using animation in lectures can be distracting and confusing rather than enhancing or easing their understanding. This may be related to their learning styles. Data was further analysed to investigate how visualisation helped when students did independent learning with it.

Learning support of visualisation in IMM OO for independent learning

The data from case studies 1 and 2 pointed out that students' learning with IMM courseware for revision after lectures improved their learning outcomes: their performance and perceptions (Section 7.4.4). This study also yields similar results. Two of the students' comments about visualisation for learning are displayed below.

> *B02S14*: In the lectures, they are doing, showing us this multimedia.... After the lectures, we can come back to the computers again, yes. We can do the same thing that we did in the lecture. So, *in the lectures we get familiar to it* and then *on our own time we can come to use that*, you know.
> *B02S15*: Very representative *like seeing a movie and it's funny*. Have a lovely feeling and at the same time learn what's going on.
> She just used them for lab time [tutorials] and used them for classes too. Just *we had a visual recall*, and see and play them with computers. It was useful I think.
> *SH:* Have you used it for your own learning?
> *B02S15*: Yes, that's I'm saying. I have used them many time, especially when I was trying to do my project. And *if I was stuck somewhere, I just went to the tutorial C++ [IMM C++] and had a look and got an idea how to do it*. Simple projects.
> *SH:* How do you consider IMM courseware you have this semester?
> *B02S15*: Yes, this *works even better with the object oriented concepts* because objects and ... objects can be more graphical. That's we have. So, *it's easier to follow some definitions* than C++. ...Yes, it's nice because they are very representative, umm. It's like seeing a movie, it's always funny. You have lovely feeling and at the same time you learn what's going on.

Excerpt 8-11 Examples: students' comments on learning support of visualisation for learning

B02S14 and B02S15's comments illustrate the benefits of integrating IMM OO for both teaching and learning. To identify how visualisation in IMM OO supported students' learning of the subject matter, in addition to interview data, their responses to open questions about 'the benefits of visualisation for learning' was analysed. The learning support students cited was classified into four categories as follows:

- demonstrating the relations of object-oriented concepts;

- illustrating abstract object-oriented concepts visually;
- providing examples;
- enhancing *Lecturer B*'s explanation during lectures.

In addition to the two students, whose comments were presented in Excerpt 8-10, there was one more student who did not consider using animations helpful for learning. His response during an interview implied that using animations did not match his view of teaching and learning of programming. He replied that: 'programming is a serious task.'

8.5.4. Benefits of integrating IMM courseware for teaching and learning from lecturers' perspectives

This section reports the results from analysing the data from interviews with *Lecturer B* and other teaching staff at Brunel University from semester 2 of 2000/2001 until semester 2 of the 2001/2002: the pilot study (Chapter 5), case study 2 (Chapter 7) and this study.

A. *Lecturer B*'s experience with IMM in the context

Lecturer B had been asked to describe how students had responded to using IMM for both teaching and learning. It was described as:

> *TK:* During the first lecture with IMM it was very difficult to get the students' attention, since that was the first time they saw someone using the IMM materials, laptop, a distance pointer to deliver lecture. It was difficult to make them silent and pay attention to the lecture. Every time the animation has been running, there was a lot of noise and laughing, a lot of talking that was not related to the topic.
> After the first lecture the students seemed to realise that IMM helps them to understand the subject better and illustration gives them better idea what I am talking about. There was no further distraction from using various facilities to deliver a lecture. There was no excitement when the animation was running. There were requests to repeat the animation in order to understand the basic idea better. The animation has been welcomed. ... During some lectures if there was some noise in the room, students asked their peers to keep quiet because they were interested in understanding the topics. ...

> From a week before the Easter break, I had a lot of enquires from students about the possibility of taking the IMM materials at home to work with. The first version of IMM was distributed via Internet. Some of the students downloaded and have been using it at home ...
> With their requests of handouts, I used traditional teaching methods with handouts, Internet-supplied materials and PowerPoint presentation for lectures. After that, I have been constantly asked to develop more IMM materials to cover the module for them. It seems the materials [traditional ones] were not enough for them after having IMM materials for their learning. They wanted to have some more IMM materials for the topics taught with traditional methods available for their learning.

Excerpt 8-12 *Lecturer B*'s description about students' responses for IMM over time

Lecturer B's description reveals that once students became familiar with IMM in lectures, they came to realise the benefits of having IMM in lectures. The last comment about students requesting more IMM for learning confirms that the students became aware of the benefits of IMM and considered it more helpful than paper-based materials for learning. To further explore *Lecturer B*'s experience, how she considered IMM to be used to facilitate student learning was explored.

Lecturer B's view on IMM use for teaching and learning

From the beginning *Lecturer B* had intended to use IMM for both teaching and learning for her programming modules. Interviews with *Lecturer B* revealed that her experiences with IMM courseware, IMM C++ and IMM OO had strengthened her view on facilitating learning with IMM through supporting both teaching and learning. She emphasised that:

> *TK:* Both, I would say. When you think about MM, you can't say you have to use it only for teaching or you can't say that should be only for learning. If you use MM, and if you want to get the best performance, best results, the most satisfactory output, you will if MM will be employed for both processes, teaching and learning ... MM will not be used actively, so much as you would like to if it is used only for one of the processes.

Excerpt 8-13 *Lecturer B*'s on an effective way to facilitate learning with IMM

As illustrated in her comment, her view on using IMM for both teaching and learning was not changed. In order to ascertain the benefits and problems she had experienced with IMM courseware for three semesters, interview data was further analysed.

Benefits of IMM in lectures

In terms of the benefits of using IMM in lectures, *Lecturer B* described that:

> *TK*: Easier to explain the main concepts, playing animation during lectures again and gain. It *helps students to visualise the concept and memorise it.* It is a big advantage for students with good visual memory.
> Visualisation is very important. Make easy understand the concepts. So, if you use MM, it's exactly like you are using a whiteboard, drawing something on a whiteboard or using prepared materials on PowerPoint. It's sort of visualisation, which is used in these methods. The difference is that on a whiteboard, you need to draw it every time. *In MM you use what has been once drawn.*

Excerpt 8-14 *Lecturer B*'s comment: A benefit of IMM in lectures

In this comment, she not only described the benefit of visualisation in general for learning, but she explained the benefit of using visualisation supported by technology. Unlike drawing a diagram on a whiteboard, once animation is created in IMM, it can be used continuously. For the benefits of using IMM in lectures, *Lecturer B* elaborated further in one of her other interviews.

> *TK*: I am trying to *save time to contact with students* and *encourage them to use the IMM material more often*. ...It is easier to explain the basic concept. If the concept is not understood, it is *not necessary to repeat the material in the lecture* again since you can refer to IMM material. I can *give them more information during lectures*. It helps students to understand very complex material quicker. Some consider the concept of pointers much easier to understand and use, rather than simple concept of using only variables.

Excerpt 8-15 More benefits of IMM in lectures

Her comment suggests that using IMM in lectures not only helped students understand certain concepts more easily but it also helped her teach more during lectures. To investigate whether using IMM for both teaching and learning encouraged and supported students' learning, the benefits that *Lecturer B* had experienced were ascertained. The following was her response during an interview.

> *TK*: it has been very good to use them [IMM] because it [IMM] *gave some students a chance to go, have a look for the materials which had been delivered before*. For this purpose, it has been put on Internet.
> ...students have been taking lectures very well. ... At least *they understand concepts and understand what's going on in the programmes*. So, I would say students would get quite happy to get IMM.

Excerpt 8-16 A benefit from using IMM for teaching and learning: revision after lectures

Students' learning with IMM C++ and IMM OO, reported in Section 8.5.2, and Section 8.5.3, revealed that using IMM in lectures had encouraged and supported students' use of IMM for learning. The last comment about students' understanding programming concepts and the concepts in the programmes suggests that student learning with IMM, especially visualisation, helped students link and apply programming concepts in programmes.

Benefits of IMM in tutorials

In terms of the benefits offered by using IMM for tutorials, *Lecturer B* described that:

> *TK:* The problems that have been covered in the IMM tutorial has been mostly solved without involving the tutor or lecturer, except the problems with compilation and understanding of compiler errors, which is lack of education in the previous semester. When the students have been using tutorials [T-IMM C++], *they tend to find answers first in the IMM material and if they have not succeeded with it, only in this occasion they contacted the tutor or lecturer for help.*

Excerpt 8-17 Benefits of IMM in tutorials

Her comment suggests that using IMM in tutorials encouraged and supported students to learn more independently and actively. As described in Section 3.3.2, one of the reasons that *Lecturer B* and *Lecturer N* had decided to use IMM was to support student independent learning. Her responses suggest that the goal had been achieved by using IMM in lectures and tutorials. In case study 1, students actively used T-IMM OO in tutorials and enjoyed the learning experience with it (Table 6-10). The results from this study confirm that T-IMM encouraged independent and active learning. She listed other benefits brought in by IMM in tutorials. One of them is that:

> *TK:* Easier for teaching staff. ... Checking students' assessments take a lot of time. Using IMM materials for tutorials reduced the time to check students' performance as the students got tasks from the materials and could use the IMM lecture materials together to solve the tasks.

Excerpt 8-18 Benefits of IMM in tutorials for teaching staff

As the comment suggests, it became easier for tutors to support students' learning in tutorials. During the pilot study, the demonstrator, who had assisted the two tutorials, had described that using IMM OO had reduced questions and he could better support students' learning. The same was echoed by the demonstrator in this study. He described that:

> *TA:* Initially I didn't think the IMM material would help. But it actually did help. In lab sessions, most students found their own answers with the IMM material. I could concentrate on helping real difficult questions. Students didn't have to wait their turn. My work became a lot easier.

Excerpt 8-19 Demonstrator's comment on teaching support from IMM in tutorials

Although his comment suggests that he realised the benefits of using IMM in tutorials, it also reveals his initial view on using IMM in tutorials: 'negative'. The data from case study 1 suggested that the teaching staff's perceptions and attitudes had affected student learning with IMM (Section 6.5.4) and their learning outcomes. Fortunately, in this study the demonstrator had been prepared before the semester started.

Learning support

In the previous semester, *Lecturer B* reported that some students' interests in C++ programming had been increased as a result of using IMM C++ although the percentage was not high.

> *TK:* I witnessed that *some students' interests in C++ programming were increased*. Unfortunately, it was not very high percentage, since the lack of understanding in C++ programming caused from the first semester and it influenced students' learning negatively. As a result, some still had problems with understanding of simple '=' operation in C++ without mentioning about understanding pointer and etc.
> During one conversation with students, I found out that *students feel much easier to draw the memory map and in some cases to explain what was going on in a programme*, rather than to draw the flowchart that displays the logic of the program. Considering the complexity of the concept, the memory map especially for dynamic memory allocation is much more difficult than the flowchart, which was taught last semester. However, it seemed that they understood the basic concepts of pointers and the memory allocation. I suspect this is a positive result of using the IMM materials for their learning

Excerpt 8-20 *Lecturer B*'s comment on students' increased interests in C++ programming

One of her aims of integrating IMM for teaching and learning was to support weak students' learning (Section 3.3.2and Section 3.5.2). Her description suggests that using IMM C++ had increased some weak students' interests in C++ programming as well as improved their understanding of it. The data from case study 2, reported in Section 7.4.3, revealed that many students, whose performance had been poor with the Pg & SD 1 module in their first semester, performed significantly better with the Pg & SD 2 module. *Lecturer B*'s description above supports that the weak students' performance improvement had been as a result of using IMM C++ for teaching and learning. To further explore the learning support of IMM courseware for weak students, who *Lecturer B* perceived had benefited most from the integration of IMM courseware was investigated.

Students who benefited from IMM in the context

For the questions about who favoured to use and benefited from using IMM, Lecture B replied that:

> *TK:* Initially mature students. They do realise there is some help.
> Most students ... they favoured MM, but some of them not. Some of them preferred some different learning styles. In some cases, you need to push them to start to use the MM. And advanced students especially, they would not favour the MM so much as *the weak ones*. So, MM is going to be for weak students rather than for strong ones.

Excerpt 8-21 *Lecturer B*'s comment on weak students' favouring to use and benefiting from IMM

Interviews with students revealed that advanced students had not considered IMM beneficial with two reasons. One was that it did not contain high level or sufficient information for them. The other was that some considered that programming needed to be learnt through doing hard practical programming tasks.

Areas required departmental support

During interviews *Lecturer B* listed things that she considered to be improved or added. One of them was some support for developing IMM courseware. She expressed that:

> *TK:* There was not enough material developed to cover the module. Obviously, the whole module developed with IMM would be advantageous.
> It would be good to have some technical support in developing IMM material, since it is very time consuming.
> Implementation of IMM, I don't like it because it takes much longer time to do it [than PP]. I would say as quite a lot of lecturers will consider MM negatively just because of time required to produce it.

Excerpt 8-22 *Lecturer B*'s comment on support required for the development of IMM

As she mentioned, developing IMM requires a longer time than creating PowerPoint slides. Institutional or departmental support is required to teach a whole module with

IMM courseware developed for the module. Other areas identified were as follows:

- Some students' negative attitudes to a new approach;
- Students' unfamiliarity to IMM;
- Lack of time for IMM development;
- IMM C++ and IMM OO supporting only low educational level students.

Introducing IMM to students in the beginning of a module in a tutorial session can improve the first and second problems. As for the three and four, departmental support is essential to further develop IMM courseware and to enrich the content. Another Lecturer B emphasised to be improved was that: 'educating and introducing a new method to teaching staff'. Teaching staff's attitudes to and perceptions of IMM-based learning influence students' learning with IMM courseware as the data case study 1 and 2 pointed out (Section 6.5.4 and Section 6.6.4).

8.5.5 Additional learning support: using IMM C++ for independent learning

The analysis of tracking data revealed that in addition to using IMM OO many students used IMM C++ for independent learning. How many students used it for learning between September and November are summarised in Table 8-3.

	September			October			November(~20th)		
	R	T	B	R	T	B	R	T	B
No of Students	21	5	1	36	23	7	14	2	2

Table 8-3 No of students who used IMM C++ (R: R-IMM C++, T: T-IMM C++, B: Both)

As displayed in Table 8-3, R-IMM C++ was used by 22 students in September and T-IMM C++ 6 students. The use of IMM C++ increased in October. Sixty six students used it; 36 students used R-IMM C++, 23 used T-IMM C++, and 7 used for both. Since students could access R-IMM C++ from T-IMM C++, it suggests that 66 students used both R-IMM C++ and T-IMM C++ in October.

The tracking data revealed that some students, who had taken Pg & SD 2 module, continuously used IMM C++ for independent learning in this semester. The others were identified as new students. During interviews with students and *Lecturer B*, it became clear that students used IMM C++ when they needed understanding of the concepts which had been taught in the previous module. The following comment is taken from one of interviews with students, which was echoed by many students. This student had neither taken the Pg & SD 2 module in the previous semester nor studied C++ before.

> *SH*: Had you have any background knowledge with C++ programming before you started this module?
> *B02S17*: No, but I've been trying to look over the notes they had last year to catch up. I have used the IMM, which I found very good actually.
> *SH:* Did it help you?
> *B02S17*: Yes, it did, I mean I've ... *about 40% of my learning comes from there for C++*. What I wanted to say was *I do find it very very helpful* and *interesting*. ... I do think it's very good to learn the principles and concepts, you know *in different ways*.'

Excerpt 8-23 Example: a new student's comment on IMM C++ helping his learning of C++

To further investigate students' use of IMM C++ for independent learning, during one of the interviews, a question about students' approaches to learning with the OOSD and OOPW modules was asked to *Lecturer B*. *Lecturer B* replied that:

> Teaching was carried on from the previous semester to this semester. So, if there had some gaps in students' understanding, they [the students] had to cover them. Cover them either with lecture notes from Internet or the IMM [IMM C++]. They needed to use either before a lecture starts. *The students went for the IMM just to refresh their memory*. Some of them won't use it, because they consider this module higher level. But I came across, when I started this module, that when *they do not understand something from the previous module, they would definitely go for the IMM [IMM C++] to have a look if they could find some information there*.
> Sometimes, I needed to inform students [new students] to have a look at the IMM because they never used it and they had no understanding of the concepts. "Well, go, and have a look, and then answer the questions."

Excerpt 8-24 *Lecturer B*'s comment on students' use of IMM C++ for learning

As mentioned in Section 8.3.1, 58 students studied this module with C++, but the tracking records in October revealed that at least 66 students used IMM C++. The data was further analysed together with interview data to explore this. The analysis revealed that although the majority of the students in this module, particularly new students, had used IMM C++ for independent learning, not all of them had used it for learning. In the previous semester, 65 more students from other courses, such as Electrical & Electronics (EE) course, had taken the Pg & SD 2 module with IMM C++. Most of these students were, at the time of this study, taking a different programming module with C++. The tracking data suggests that some of these students were using IMM C++ for learning. It can be interesting to explore who from other modules used IMM C++.

Another thing revealed from interviews with students was that few had used other materials from the previous semester for learning. The following students' comments enlighten the effectiveness of IMM courseware for learning and at the same time emphasise the importance of encouraging students to use IMM for learning.

> Didn't use it [IMM C++ last semester]. But I *used that after last year because I didn't understand C++ at all*, so I tried to understand it in summer. I found it was *very useful for me because it was interesting and easy to understand.* I *liked it.* ... I didn't know we had them before. During summer, I had problems with C++. Dr Kalgavona told me we had them. So, I downloaded and used them at home.

Excerpt 8-25 A student's use of IMM C++ after the semester and benefits realised

> Yes, I mean he [interviewee's friend] just downloaded it and took it home and he went through it. The only thing was that it was a bit too late for him because you know, he already started his assignment. But the thing was that he kind of *didn't understand where everything in his programme* was going. So the point is it actually helped him, even though it was backwards. *Helped him understand basics of his own programme.* ...He *could see it like line by line* instead of just seeing like, you know, this half of pages of code after that.

Excerpt 8-26 Understanding improved by the use of IMM C++: realised later

8.6. Summary

This chapter reported the third case study conducted to investigate student learning with IMM OO in lectures and tutorials. In case study 2, students' prior experience was identified as a factor that affected their approaches to using IMM C++. Interviews with *Lecturer B* enlightened this more clearly. She described that in the previous semester, most students used R-IMM C++ because it had been introduced in lectures and students had become familiar with it. As for T-IMM C++, they had never seen it and many had not made an attempt to use it. Interviews with students suggested this to be true.

To better facilitate students' initial use of IMM OO for learning, *Lecturer B* requested students to try it in the first tutorial. Although some students still showed reluctance to try it for their own learning, the majority soon realised the benefits of it. The students, who had not used IMM C++ for learning, started to use IMM OO because they were *forced* to try it. This helped them realise the benefits of T-IMM for learning. Interviews in October 2001 and January 2002 revealed that students, who had used hyperlinks, had become more active users of IMM OO. These students emphasised the learning support provided by tasks and hyperlinks. The benefits they listed were, first of all, tasks in T-IMM allowed them to test what they had learnt in lectures. Secondly, with hyperlinks leading them to related information in R-IMM OO they could identify areas to improve. Thirdly, it helped them correct their misconceptions. In addition, their realisation of the benefits of T-IMM OO encouraged them to use T-IMM C++ for learning. The tracking records in October for T-IMM C++ proved their increased use for independent learning.

Analysis of tracking and interviews data revealed that a large number of students used IMM C++ for independent learning. Two reasons were identified. One was that new students to the OOSD and OOPW modules used IMM C++ to gain knowledge of what had been taught in the previous semester. The other was that when the students from the

Pg & SD 2 module realised their background knowledge was insufficient, they used it to refresh their memory or to gain an understanding of the knowledge required. Other materials, PowerPoint slides or Internet-based, were available, but most used IMM C++ for learning.

The analysis of interview data with *Lecturer B* and other teaching staff suggested that using IMM for both teaching and learning not only supported student learning but it also supported teaching. Teaching in lectures and tutorials became easier with support from IMM courseware. In lectures students came to understand abstract concepts more easily with visualisation, which enabled *Lecturer B* to spend more time on complex concepts or to teach more. In tutorials, with IMM courseware students found most of their solutions by themselves; they preferred to find their own solutions first from IMM OO. This helped the teaching staff support students with difficult questions.

In addition, the data from case studies 2 and 3 revealed several factors that affected student learning with IMM, and they were: students' previous experience and familiarity with IMM; both students' and teaching staff's attitudes to a new approach; and the time of introducing IMM to students. Comparison of the data between the three case studies suggests that to facilitate student learning effectively, IMM courseware should be integrated from the beginning. This will improve students' perceptions of the subject matter and encourage them to learn more actively. Other factors such as students' learning styles or their preferences of learning methods seemed to affect their learning with IMM. However, the most significant factor affecting student learning was their actual use of IMM, which was already revealed from case studies 1 and 2.

CHAPTER 9 CONCLUSION

Effective ways to facilitate student learning of programming with IMM have been explored in this thesis. Drawing on initial research (Chapter 2) and a preliminary study (Chapter 3), an initial design and integration approach was proposed (Chapter 4). The primary emphasis of this approach lies in enhancing the student learning experience with the use of IMM courseware in lectures and tutorial. An empirical study was designed and conducted to evaluate the effectiveness of the approach in supporting teaching and learning processes (Chapter 5, 6, 7 and 8). Two IMM courseware were developed and integrated into four programming modules at Napier and Brunel Universities. Students' learning and lecturers' teaching experiences with the courseware were explored, and the approach was revisited. The key findings are summarised and explored here with full details in Appendix 13.

This chapter presents a revised design and integration approach informed by the findings from the study. Reflecting on the factors identified as affecting student learning with IMM, this thesis presents a design and integration process with IMM for teaching and learning. Finally, this thesis draws to a close by suggesting future work.

9.1. Design and integration approach revisited

As discussed in Section 2.1, facilitating student learning requires creating a learning context which affords a 'deep' learning. To achieve it with IMM, considerations need to be given to three areas. One is to design IMM courseware, which supports the learning process and is appropriate for the subject matter and learning context chosen. The second is to integrate the courseware into the curriculum in a way that can optimise the learning effects and benefits of the courseware. The third is to create an environment in which students are encouraged to use the courseware for learning. The initial design and integration approach, presented in Chapter 4, was developed to promote the three aspects. The approach, as described in Section 4.1, aimed to improve the quality of student learning with IMM courseware through creating a learning context which

- promotes active learning and reflective thinking;
- supports collaborative and interactive learning;
- increases students' motivation and interests in the subject matters they study;
- supports teaching and learning abstract concepts.

The results from the empirical study suggested that student learning experience was enhanced by the use of IMM courseware for teaching and learning: their performance and perceptions of the subject matters improved (Section 6.5, 6.6, 7.4 and 8.6). However, some weaknesses were also identified, particularly in supporting student learning with different knowledge levels. The IMM courseware in the study contained information with which students could only build fundamental understanding of the subject matters as the materials were primarily targeted to support weaker students' learning. Students were supplied with paper-based materials and expected to expand their knowledge with them. However, the results suggested that more resources should be added to satisfy students with different knowledge levels, especially those with a preference of learning with IMM materials. The main findings were reflected upon and revisions made to the initial approach. The revised approach is illustrated in Figure 9-1.

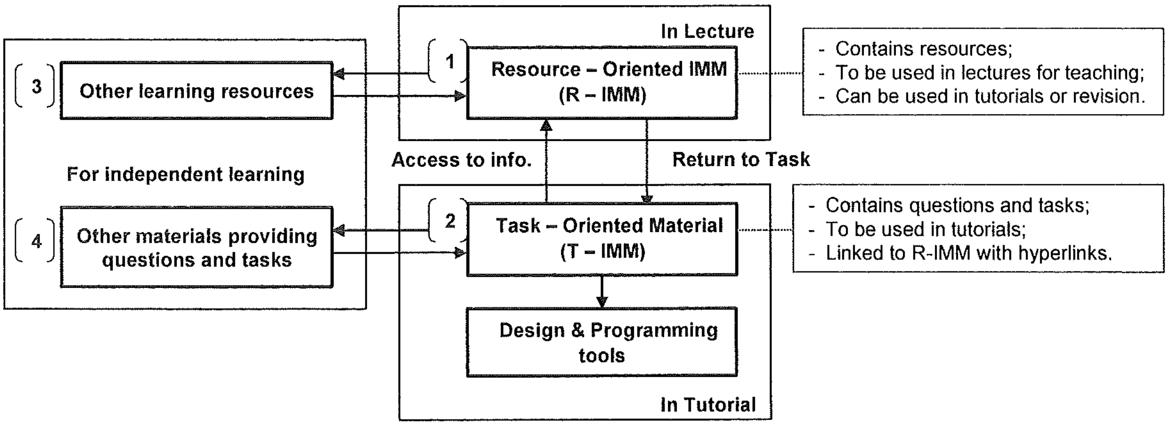


Figure 9-1 A revised design and integration approach

The main features of the revised approach and how it facilitates student learning are discussed below.

9.1.1. The architecture of IMM courseware and its integration

The IMM courseware consists of two types of learning materials, which is similar to the initial approach: one containing resources (R-IMM) and the other tasks (T-IMM). R-IMM is to be used in lectures and later for revision, and T-IMM in tutorials. A new feature in the courseware is the integration of other (on-line) learning resources, which will be discussed in Section 9.1.3. The primary benefit of the architecture of IMM courseware and its integration lies in creating a learning environment which, firstly, facilitates the use of IMM courseware for learning (see Section 8.6.2), and secondly, enhances student learning (see Section 7.4.5). Using IMM courseware in lectures and tutorials can help students become familiar with the courseware, which will as a result encourage them to use it for learning (see Section 7.4 and 8.6). It will also enhance student learning through: supporting the 'iterative' teaching and learning processes (see Figure 4-4); creating collaborative and interactive learning environments; and promoting active learning and reflective thinking (see Section 6.6 and 8.6.2).

- **Supporting the 'iterative' teaching and learning processes**

IMM courseware (R-IMM) in lectures can assist lecturers' teaching of abstract concepts with visual effects (see Section 8.6.3 and 8.6.4). When students use it in tutorials or for revision after lectures, they can apply and test their understanding in problem-solving context (with T-IMM). From T-IMM students can access related information in R-IMM. Their understanding will be enhanced by revisiting the same material that was already presented in lectures. When teaching with the IMM courseware continues in the subsequent lecture, students will attend it with an improved understanding of the concepts delivered in the previous lectures from their learning with it in tutorials. It will help the lecturer teach new concepts and students conceptualise them linking their existing knowledge (see Figure 4-4, and Section 8.6.3 and 8.6.4). How the use of the

IMM courseware in lectures and tutorials supports the learning process is illustrated Figure 9-2 with Fowler and Mayes' learning framework.

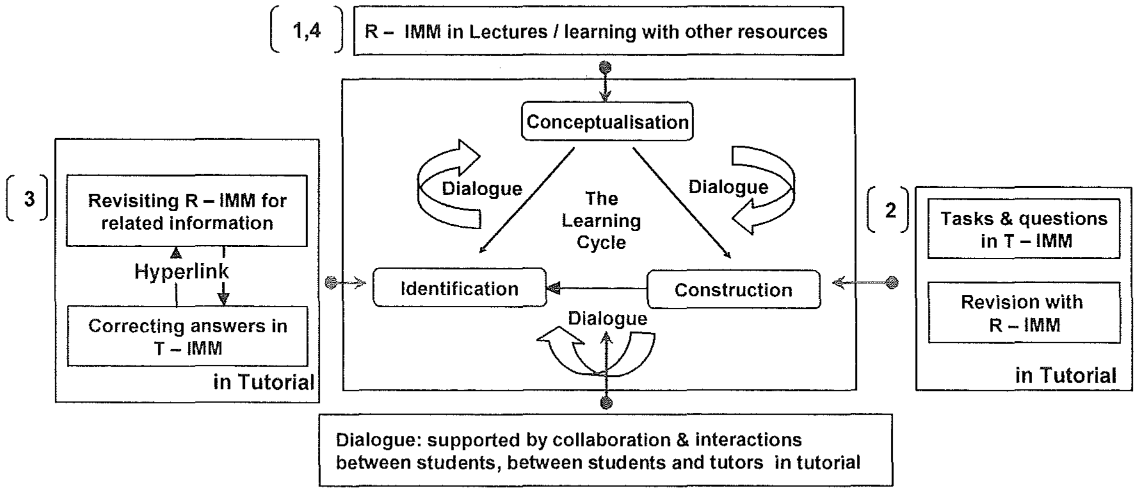


Figure 9-2 Revised design & integration approach supporting Fowler & Mayes' learning framework

As described in Section 4.4.1, the architecture and design features of IMM courseware and its use in the learning context support the three phases and dialogue. Enhanced in the revised approach is the 'conceptualisation/re-conceptualisation' phase supported from students' learning with other resources.

- **Creating collaborative and interactive learning environments**

Using IMM courseware in tutorials can create an environment which promotes interaction and collaboration between students and tutors. Questions and tasks provided with feedback (model answers and hyperlinks) in T-IMM can promote interaction between students and the material. This will provide students with control of learning and encourage them to be actively involved in their learning. Applying and testing their understanding with T-IMM will make students' misconceptions explicit (see Section 7.4.6 and 8.6.2). This will help them raise focused and clear questions when they need clarification or more information. It will promote collaboration and interaction between students and their tutors (see Section 6.5.4). Tasks and feedback in the context can also promote active learning and reflective thinking, which will be discussed below.

9.1.2. Feedback (hyperlink) design in problem-solving contexts

As mentioned in Section 1.2, questions and tasks provide a means of stimulating reflective thinking, testing understanding and encouraging students to try to solve them. However, when they are given without appropriate intrinsic or extrinsic feedback, they can also discourage students to solve them actively. As the results from the empirical study in students' interaction with paper-based programming tasks versus tasks in T-IMM (i.e. Section 3.3, 5.4.4 and 6.6.2) indicated, many do not actively seek help from their tutors when they need support. One main reason identified was students did not know what information they needed to solve the tasks. To encourage students to try to solve tasks with either paper-based or IMM materials, it is essential to provide a means to obtain the help or information required. A solution used in the design and integration approach was providing hyperlinks as part of feedback.

In T-IMM, hyperlinks were embedded as part of feedback for questions and tasks. To explore the learning effects of hyperlinks in problem-solving contexts, three different variations of T-IMM were developed and evaluated: one without hyperlinks, the second provided with questions (*static*), and the third with model answers when the questions were answered incorrectly (*dynamic*). The results showed that 'dynamic' hyperlinks improved students' performance most effectively (see Section 6.5.2). It supported 'goal-action-feedback cycle' and reflection. It helped students become aware of their misconceptions; identify areas where their understanding is insufficient; correct their misconceptions through revisiting R-IMM (*action and feedback*); and in the process reflect on what they learnt in lectures (*reflection*) (see Section 8.6.2). However, it was also revealed that 'static' hyperlinks offered different learning support (see Section 6.5.2). They helped students articulate their answer, and it was especially beneficial when students did not have sufficient knowledge to test and when they preferred to research. To benefit from both 'dynamic' and 'static' hyperlinks, the revised approach proposes to embed them both. This will provide a more flexible learning approach, and students will benefit from both hyperlinks types in problem-solving tasks. As for other learning situations, i.e. for other disciplines or virtual learning environments, the designer may choose one suitable for the contexts, which can be interesting to further explore.

9.1.3. New feature: integration of other learning resources

As already mentioned in Section 9.1, one main weakness of the IMM courseware in the empirical study was that they did not contain sufficient information to accommodate the needs for advanced students or students who liked to learn with IMM courseware. In the revised approach, a new feature is added to improve this: integration of other learning resources while keeping the content structure of IMM courseware presented by the initial approach. As illustrated in Figure 9-1, a section containing hyperlinks for other resources is added to IMM courseware (see 'Hyperlinks' in 'Help' Section from 'IMM_OO_lecture' in the CD) in which students can visit other resources or websites. This will offer more flexible learning approaches and control of learning to students.

9.2. Designing and integrating IMM for teaching and learning

Integrating educational technologies to facilitate student learning requires a systematic and holistic approach. Teaching and learning are complex and iterative processes, and various personal and contextual factors affect them. To successfully integrate educational technology, we need to consider its impact in the teaching and learning contexts. After briefly summarising the factors affecting student learning with IMM identified from the empirical study, this section will present a design and development process with IMM for teaching and learning, developed from the findings of the study.

9.2.1. Factors affecting student learning with IMM

The empirical study results revealed that students' approaches to using IMM influenced their learning outcomes and benefits of IMM realised (see Section 7.4.3), and they were affected by various personal and contextual factors. The relationship between the factors and students' approaches to using IMM is illustrated in Figure 9-3.

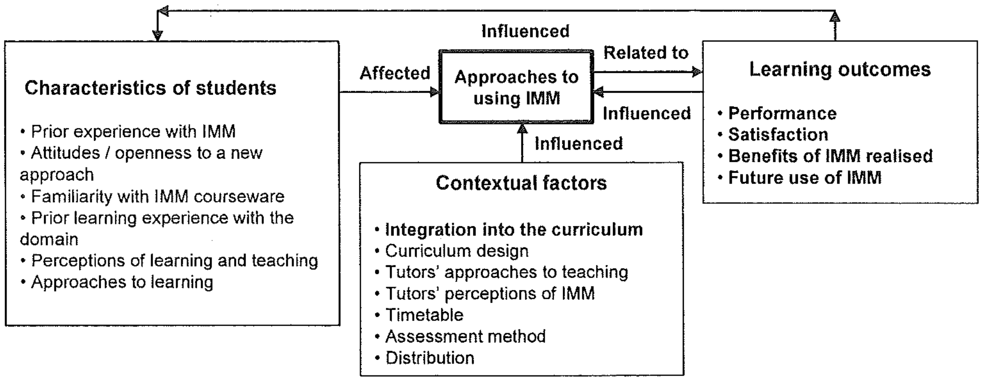


Figure 9-3 Factors affecting students' approaches to using IMM

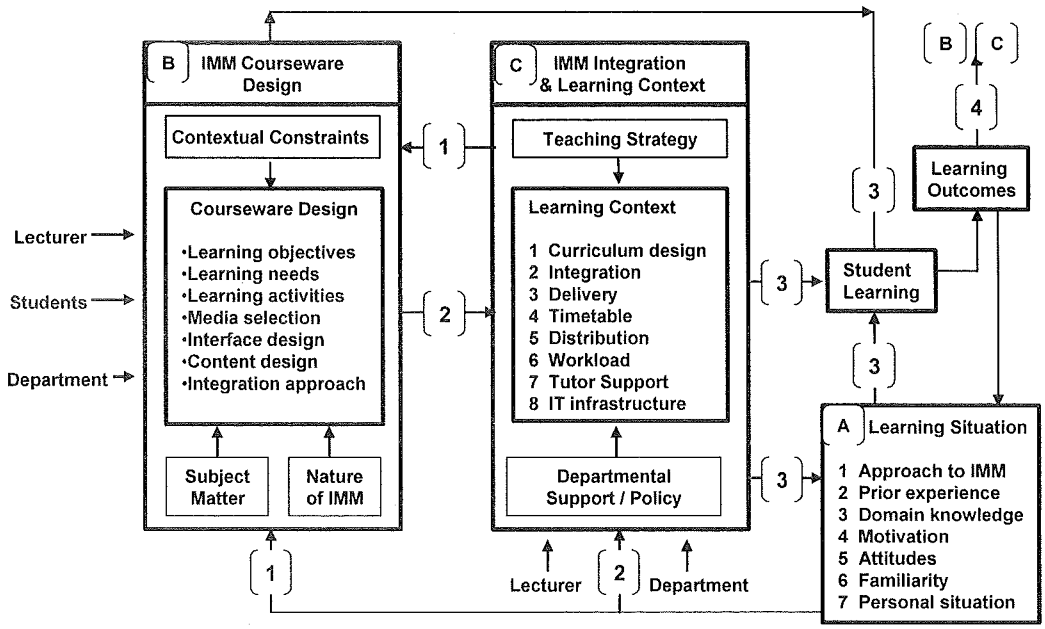
The factors affecting students' approaches to using IMM courseware are described in detail in Section 7.5 and Section 8.7. A summary of major factors is presented in Table 9.1

Personal factors		
Prior IMM experience	Yes	More positive reaction, especially in the beginning/ Enjoyed learning with IMM more/ Used IMM courseware more actively.
	No	More reluctant to try it/ Responses gradually became positive.
Attitudes & openness	Positive	Used IMM more/ enjoyed learning with it more.
	Negative	Reluctant to use IMM for learning.
Familiarity with IMM	Familiar	Actively used it for learning (actively used R-IMM because it was introduced in lectures).
	Unfamiliar	Reluctant to try it (tried to avoid using T-IMM initially).
Prior learning with the domain	High mark	Maintained their learning strategies used in previous semester.
	Low mark	More actively used IMM.
Contextual factors		
Tutors' attitudes & perceptions of IMM/ support	Positive	Active learning support (approached students to find out if they needed help and encouraged their learning with IMM).
	Negative	Passive learning support (help given when asked).
Timetable		Frequent lab sessions supported student learning with IMM more effectively (frequent lab sessions with IMM supported learning more effectively than less frequent and longer ones).

Table 9-1 Summary of factors affecting students' approaches to using IMM courseware

9.2.2. Design and development process of IMM for teaching and learning

As mentioned already, students' familiarity to IMM courseware affects their use of it for learning. We need to create a learning environment in which students can become familiar to the courseware and motivated to use it. Figure 9-4 illustrates a design and integration process with IMM. The process consists of three phases and the factors to be considered. The three phases are (1) designing IMM courseware; (2) integrating it into the curriculum; and (3) facilitating learning with it. The factors are (A) student learning situations, (B) IMM courseware design, and (C) IMM integration and the learning contexts. The relationship between the phases and factors is discussed below.



Process: [1] Designing IMM; [2] Integrating IMM; [3] facilitating learning with IMM; [4] Restarting the iterative process. Influential factors and stages in the process: [A] the characteristics of students; [B] IMM design; [C] IMM integration and learning context, and learning context design

Figure 9-4 Design and development process of IMM courseware for teaching and learning

- **Design and integration processes [1, 2]: factors to be considered [A, C]**

To facilitate student learning with IMM, firstly, students' learning situations need to be considered. As discussed in Section 2.1 and Section 2.2, students' approaches to learning are related to their learning outcomes, and there are various factors affecting students adopting approaches to learning. Identified are their conceptions of learning, background knowledge, their perception of the learning context and personal situation. As for facilitating learning with IMM, added from the empirical study findings are students' prior experience with IMM, familiarity with IMM courseware and prior learning experience with the domain (mainly performance). To facilitate learning with IMM, it is important to create a learning environment in which students become aware of the benefits of IMM and motivated to use it. Integrating IMM for both teaching and learning can be a way to create such an environment as discussed in Section 9.1.

Secondly, external (contextual) factors should be also considered. The design and integration of IMM courseware should be suitable for the learning and teaching contexts, and the contexts should be designed to support the design and integration approach with IMM taken. For example, IMM courseware should be designed and integrated seamlessly into the curriculum, i.e. curricular activities and other course materials. As for teaching strategies, they should be employed to enhance student learning experience with IMM courseware and to encourage them to use it for learning. In addition, institutional support is required for staff development, IMM courseware design and development, effective distribution and delivery to enhance student learning experience.

- **IMM courseware design and integration [B, C]**

As illustrated in Figure 9-4, IMM courseware should be designed and integrated considering the nature of IMM and the chosen subject matter as well as the constraints brought in by students' learning situations and the learning context. First of all, IMM courseware design should be suitable for the chosen domain and context. For example, the design and integration approach, illustrated in Figure 9-1, proposes to use IMM courseware in lectures and tutorials. Interface and content design should be appropriate for both teaching and learning, and media should be selected accordingly. Secondly, IMM courseware should be designed and integrated to support the learning activities required for learning. They can be designed either within the courseware itself or with it in the learning context. For example, when IMM courseware is used in tutorials, learning activities can be supported by the courseware or they can be promoted by interactions and collaborations between students and tutors.

- **Iterative design and integration processes with IMM [4]**

The design and integration process should restart reflecting on students' learning outcomes and lecturers' teaching experience to better support student learning with IMM.

This study, reported in this thesis, was conducted with the bottom-up approach to support the needs identified from the teaching and learning situations of programming at Napier and Brunel Universities. To exploit the full potential of IMM for teaching and learning, further research is required in a wider context investigating its impact on teaching and learning and exploring the departmental support required. The following section outlines the areas where further study can be beneficial.

9.3. Future work

Further study can be conducted in the following three areas. Firstly, longer investigation in student learning of programming with IMM courseware is required. The IMM courseware in the study contained resources and tasks to support student learning with only part of the programming processes. Evidence with design and programming tasks suggested that student learning with the courseware helped them approach and view the processes more holistically. Study with more developed IMM courseware can investigate the effectiveness of the design and integration approach in promoting students to adopt a holistic approach to the programming processes. Secondly, the approach can be further explored for other learning situations, i.e. for other disciplines and for different learning contexts.

Thirdly, the learning effects of hyperlinks should be further explored. This thesis explored the effects of hyperlinks as part of feedback in problem-solving contexts. The IMM courseware in the study was designed deliberately to deny students' access to T-IMM from R-IMM. The button for 'assessment' in R-IMM was disabled. Further study should be conducted to explore the effects of hyperlinks when students can access T-IMM after learning with R-IMM. Enabling the 'assessment' button in the main menu bar will allow students to directly access T-IMM from R-IMM. In addition, investigating the learning effects of 'dynamic' and 'static' hyperlinks in other learning situations can be interesting.

APPENDIX 1 QUESTIONNAIRE FOR NEEDS ANALYSIS

Student Name:	Programme:
Age:	Sex: Male / Female

Please tick a box or fill in the blanks to answer the questions.

1. How would you grade your current understanding of Software Development (SD)?

< Poor	----------	----------	----------	Excellent >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2. How difficult/easy would you grade SD concepts to understand?

< Very difficult	----------	----------	----------	Very easy >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

3. How important would you grade SD in your programme of study?

< Not at all	----------	----------	----------	Very important >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

4. What 3 things did you find most difficult to understand?

1.
2.
3.

5. What 3 things did you find easiest to understand?

1.
2.
3.

6. How much use did you make of the Toolbooks?
   - ☐ Never
   - ☐ All the time
   - ☐ Initially all the time, then less used as my understanding improved
   - ☐ More later as I found my grounding was insufficient

7. How did you use the Toolbooks?
   - ☐ Never used
   - ☐ As main resources to improve my understanding
   - ☐ As reference materials to look up a topic

8. How did you perceive the Toolbooks?
   - ☐ As a teaching aid for the tutor
   - ☐ As learning materials for the students

9. Should the Toolbooks be both a teaching and a self-study guide?
   ☐ Yes ☐ No

10. Do you consider you could learn from the Toolbooks independent without a tutor?
    ☐ Yes ☐ No

11. Did the Toolbooks help you understand the abstract concepts?
    ☐ Yes ☐ No

If yes, what makes the Toolbooks successful? / If no, what are the Toolbooks failings?

12. Was the text or the picture of more importance to you when you used the Toolbooks? What were the relevant weightings?

Picture relevance	Text relevance
☐ 100%	☐ 0%
☐ 75%	☐ 25%
☐ 50%	☐ 50%
☐ 25%	☐ 75%
☐ 0	☐ 100%

13. How much did the visualisation assist with your understanding of the abstract Object Oriented (OO) concepts?

    ☐ None ☐ Very little
    ☐ Some use ☐ Very beneficial

What part, if any, did the visualisation assist with your understanding of the abstract OO concepts?

14. How easy was it to find the topic you wanted to find in the Toolbooks?

- ☐ Very easy
- ☐ Reasonably easy
- ☐ A little difficult
- ☐ Very difficult

15. If the Toolbooks are to be redesigned, what features would you additionally require (i.e. introductory list of objectives, index at start of each book, glossary of terms or search facility)?

16. If the Toolbooks are to be redesigned, what features would you require to modify?

17. Any other comments?

18. Would you like to participate in a focus group or interviews to share your experience of studying SD module? The meeting will last for no more than 1 hour.

If you are willing, please write down your e-mail address.

APPENDIX 2 EVALUATION OF TOOLBOOKS & POWERPOINT

A. Electronic materials used for lectures and learning at Napier University

The Toolbooks were assessed in terms of the architecture of the Toolbooks and its use in the context, content design - content structure of each Toolbook and information representation-, interface and navigation.

Materials

The Toolbooks were designed to deliver lectures for the SD 1B module for the whole semester. They contained the object-oriented concepts with animations, design and implementation processes with programming examples. The main features used for information representation were text and animation. In addition, the user was given with an input option in simple tasks, and they could experiment with different input data.

Architecture of Toolbooks & their use in the context

Toolbooks consisted of 16 separate files: Toolbook1.tbk, Toolbook2.tbk ... and Toolbook16.tbk with no opportunity to navigate between them. The Toolbooks were installed on the university network, and students could access them during tutorials or on their own time in computer labs. Students could not take the Toolbooks to for home use as they had no run-time environment available.

Content structure of each Toolbook

Each Toolbook contained one main topic, and they were divided into several subtopics. Each page displayed information about a subtopic, and a Toolbook finished with a summary page. The content in a Toolbook was structured simply, and information was presented in a step by step manner.

Information representation (design features)

The main features used in the Toolbooks were text and animation. Text information was brief and clear to understand. Simple animations were used together with text information. For abstract OO concepts, animations illustrated the concepts relating them to real life objects and with programming they showed step-by-step processes of programming processes relating them to concepts.

Interface

The interface was designed in a simple manner. The screen was divided into four areas. The top was for the title of each Toolbook, the right for the text information, the left for animation and the bottom for the navigation panel. When there was animation presented on the left, a 'Play' button appeared on the bottom left below the animation. The user could play the animation as many times as they liked.

The simplicity of the interface design was suitable for teaching; however, some areas required improvements. One was that the screen size was small (400 x 300 pixels). The second was that text size 10 was used, which was difficult to be read in lectures. The third was that the colours, particularly background colour, used for the interface were not user friendly. The main colours used were black, grey and dark green. Figure A-1 shows a sample screen of a Toolbook.

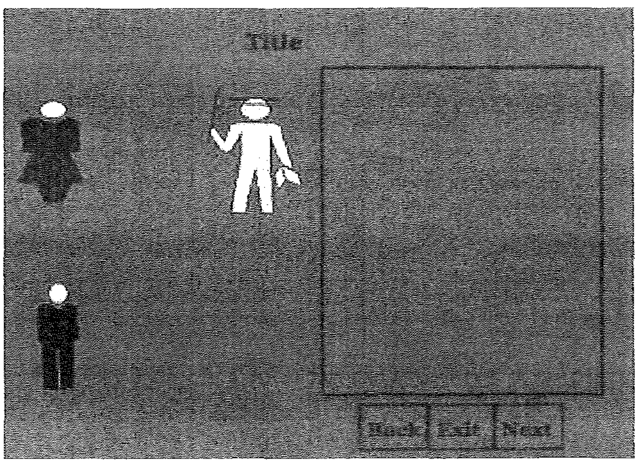


Figure A-1 Interface of the Toolbooks

Navigation

The 'Back', 'Next' and 'Exit' buttons (see Figure A-1) provided linear navigation only. There was no menu for random access to subtopics within a Toolbook.

The navigation between Toolbooks was not available. The 16 Toolbooks were designed separately and named Toolbook1 … Toolbook16, which did not give any indication of what they contained. Nor was there a main menu allowing students to the set of Toolbooks. Accessing specific information was problematic for studying. Students needed to explore each Toolbook and their pages. This was one of major weaknesses of Toolbooks for use by learners.

Distribution

Students could access the Toolbooks from the university intranet and home use was difficult as the authoring tool, Toolbook, was required to use them.

B. Evaluation of electronic materials at Brunel

The materials were designed aiming to assist students' learning with visualised OOP concepts with C++. They were designed in PowerPoint, and did not have a unified interface. However, there were some consistency in information presentation with and without animation, interface and navigation within animations. The materials were assessed in terms of the architecture and their use in the context, content design (content structure & information representation), interface, navigation and animation design.

The architecture of PowerPoint slides and their use in the context

The materials consisted of several PowerPoint files. As for the names of the PowerPoint files, they indicated what information each file contained: OOO_HowObjectsBehave, OOO_HowObjectsCommunicate, … and PS_ProblemSolvingSequence_Pseudo-code.

Content structure

Each PowerPoint file consisted of many slides with related topics. Some were displayed text only and the others were displayed with text and animations.

Interface

A title was placed on the top left side of the screen. Apart from placing a title on the top left, no uniformed layout was used with the PowerPoint materials. The control button for animations was mostly placed on the top left below a title, but sometimes the location changed. Within Flash animations, 'Help' button was placed on the top left. As Flash animations were designed separately from the PowerPoint slides, they also had the same titles. This made a title appear twice where animation was embedded. To direct attention, strong colours such as red and yellow were used. Overall, much improvement is required for interface design.

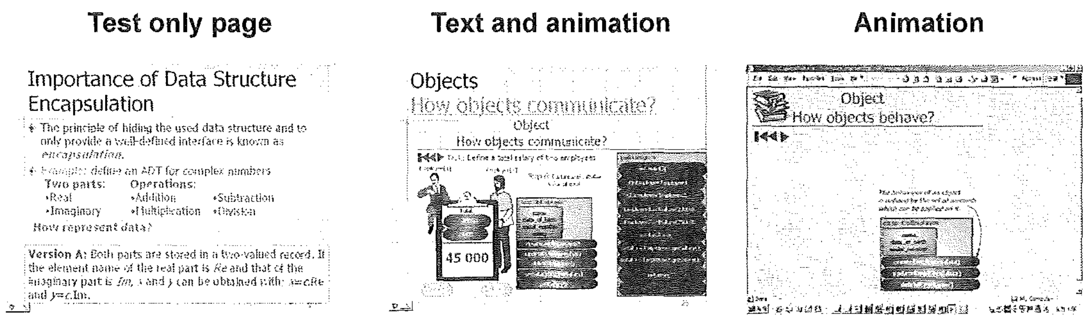


Figure A-2 Sample screenshots of some slides in the PowerPoint materials

Navigation

The PowerPoint files provided linear navigation only. Animations also provided linear navigation with the 'Back' and 'Next' buttons. Finding specific information was as similarly problematic as the Toolbooks at Napier University. However, each PowerPoint file had a name that clearly indicated the main topic it contained. Students yet needed to go through each slide to find the topic within the file.

Content design (information representation)

Information was presented with text and animation. Animations were designed to illustrate programming processes and the relations between them. They illustrated OO concepts and a design model with real life objects through linking the relationship between, related a design model to programming, and explained implementation processes step by step.

Distribution

The materials were uploaded onto Lecturer B's website, so students could access them from the Internet and university Intranet.

APPENDIX 3 CONTENTS OF IMM OO AND IMM C++

Content structure of R-IMM OO

The content of R-IMM OO is structured into several units. The units are expounded on basic principles of OO, and each unit is built up previous units. Each unit begins with objectives and ends with summary. Figure A-3 shows the content structure. Here only the topics contained in Unit 1 are presented, and the rest could be found in the OO courseware itself in the CD.

Unit 1: Objects and message passing

- Objectives
- Message passing I
- Message passing II
- Message passing III
- Message results
- Transformer messages
- Message targets
- Message propagation
- Illegal messages
- Summary

Unit 2 Objects and state

Unit 3 Collaborations

Unit 4 Objects and classes

Unit 5 OO analysis and design

Unit 6 Classes and attributes

Unit 7 Classes and operations

Figure A-3 Content structure of the IMM courseware

The content of T-IMM OO is structured to support student learning with R-IMM OO. It is structured into several units, and each unit matches the lesson unit in R-IMM OO. The tasks in T-IMM OO requires students' understanding of the topics covered in the preceding lesson units in R-IMM OO and hyperlinks are embedded for students to access them as well as the corresponding lesson unit.

The content of IMM C++

The structure of the R-IMM C++ is presented in Figure A-4. Only the topics contained in Unit 1 are presented, and the rest could be found in the IMM C++ itself.

Unit 1: Variable

- Objectives
- Addresses in real life
- Computer memory
- Type of variable
- Value of variable
- Address of variable
- Variable description
- Declaration
- Variable usage
- Access to a variable value
- Access to a variable address
- Summary

Unit 2 Reference variable

Unit 3 Introduction to pointer

Unit 4 Pointer

Unit 5 Pointer to pointer

Unit 6 Lvalues and Rvalues

Unit 7 NULL pointer

Unit 8 Dynamic memory allocation

Unit 9 New operator

Unit 10 Delete operator

Unit 11 Structure

Figure A-4 Content structure of R-IMM C++

As for T-IMM C++, the same design principles of IMM OO were applied.

APPENDIX 4 PRE-QUESTIONNAIRE & PRE-TEST

Name:	Programme of Study:

Please complete both sections.

All replies will be treated in confidence.

Section A

1) How would you grade your current understanding of Object Oriented Design with C++?

Poor <...> Excellent				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2) How easy/difficult would you grade OOD concepts to understand?

Very easy <...> Very difficult				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

3) How important would you grade OOD in your programme of study?

Not at all <..> Very important				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

4) What 3 things did you find most difficult to understand?

1.
2.
3.

5) What 3 things did you find easiest to understand?

1.
2.
3.

6) How much do you enjoy studying OOD?

Not at all ……………………………………………………………….> Very much				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

7) How much have the electronic materials helped your understanding of OOD?

Not at all <……………………………………………………………..> Very much				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

8) Any other comment?

Section B

Please write answers in the space provided. You can continue answers overleaf and extra paper can be provided if necessary.

1. In the following scenarios, identify the sender object, the recipient object and the message.

(a) A customer asks an assistant for available sizes of jeans.

(b) A customer asks the assistant whether the shop has home delivery service.

(c) The assistant asks a customer for the credit card details.

(d) Hotmail service asks the user for their passwords.

a)
b)
c)
d)

2. At home you control your Hi-Fi stereo with an infra red remote control. Assume that the Hi-Fi stereo is already switched on and the channel mode is set up on FM.

(a) When you select AM by pressing the appropriate button on the remote control what message is being sent and who is the sender and who is the receiver?

(b) What further message is sent as the consequence of this first message, and again who is the sender and receiver?

(c) The result of this message passing is, of course, the change the broadcast channel to AM. Identify the message received by the Hi-Fi stereo.

a)
b)
c)

3. The tax inspector asks a family for their total income.

(a) How is this received?

(b) How does the family members obtain his/her own income?

a)
b)

APPENDIX 5 POST-QUESTIONNAIRE & POST-TEST

Name:	
Course and Programme of Study:	

Please complete both sections.
All replies will be treated in confidence.

Section A

1) For each statement please indicate whether you strongly agree, disagree, neither agree or disagree, agree, strongly agree.

		strongly disagree	disagree	neither agree or disagree	agree	strongly agree
a	I found this application *easy* to use					
b	I *enjoyed* using application					
c	I now have *a good understanding* of messages and objects					
d	The *animations helped me understand* the subject better					
e	The extra features (help, glossary) were helpful.					
f	I *felt in control of my learning* at all times					
g	I would like to use *more interactive multimedia learning applications* like this					
h	I will use this application when *revising*					
i	Hyperlink in the tutorial material was very useful for problem solving					
j	I feel that the ability to access information directly has helped me understand this subject better					
k	The ability to access information directly with hyperlink will help me understand OO concepts better					

2. Would you willing to be interviewed (e-mail interview) on your experience of using this application? If you are willing, please write down your email address or phone number so I can contact you to arrange a time.

3. Please write down any general comments overleaf.

Section B

Please write answers in the space provided. You can continue answers overleaf and extra paper can be provided if necessary.

1. At home you are busy with washing up. The washing machine is set at cotton program. To wash a woollen sweater, you reset the washing machine setting.

(a) Who sent what message?

(b) Who was the receiver of the message?

(c) What was the effect on the washing machine?

(d) What kind of message was sent to the washing machine?

a)
b)
c)
d)

2. A student put his switch card in an automated bank teller machine (ATM) and entered his password. Next, he wants to withdraw 10 pounds.

(a) Who acts as the sender and the receiver.

(b) What message was sent?

(c) What possible other messages might we envisage between the sender/receiver?

(d) What is the effect of this message on the receiver?

a)
b)
c)
d)

3. The superstore Tesco provides on-line service. Through this service you can search any type of products in which Tesco supplies. You can also interrogate the service to determine if a given product is available or out of stock, also you can purchase any required products.

(a) When you use this service, who operates in sender mode and who in receiver mode?

(b) Is it strictly true to say that the supermarket is the receiver?

(c) How many different types of messages can the supermarket customer issue to the system?

a) b) c)

4. A teacher asks a pupil their address.

(a) What message is the pupil object being asked to accept?

A teacher asks one pupil for the address of the pupil on their immediate right.

(b) Now how many message types are pupil objects prepared to accept and what are they?

(c) Explain how the messages are routed through the system.

a) b) c)

APPENDIX 6 TEST 1 IN CASE STUDY 1

Napier University
School of Computing

CO12005: Software Development 1B
Object Oriented Design with Java (Pre-Test)

Organisation

The aims of this pre-test is to examine your analysis and design skills. There is NO subject assessment mark associated with this activity. We offer it as a measure of your current understanding of the subject.

Specification

A company employs an number of contract IT staff. The company hires these contractors temporarily to its customers. The staff have a number of attributes such as their name and salary.

The organisation requires a computerised system to support their human resource management. The company needs to be able to obtain a full list of employees. For taxation purposes the company also needs to know the total salary bill. The company needs to find if they have staff to meet the needs of their customers. Some customers wish to employ a contractor with particular skills (e.g. Java or database skills) and the company need a list suitable staff.

Analysis and Design

(1) Present a class diagram for the problem, and a short explanation for the model. Identify and consider any major decisions that you are making. What might we deem as other appropriate attributes for an employee? What could be the attributes for the organisation?

(2) Produce a collaboration diagram showing a particular configuration of objects.

(3) Present collaboration diagrams and a short description to show the execution patterns for the following operations:

(a) the operation to display the full contract staff list;
(b) the operation to display staff that have the necessary skills for a customer;
(c) the operation to display the total salary bill.

APPENDIX 7 TEST 2 IN CASE STUDY 1

Napier University
School of Computing

CO12005: Software Development 1B
Object Oriented Design with Java (Post-Test)

Organisation

The aims of this post-test is to examine your analysis and design skills and compare the results against the pre-test outcomes. There is **NO** subject assessment mark associated with this activity. We offer it as a measure of your current understanding of the subject.

Specification

A university enrols a number of students. The students have a number of attributes such as their name, matriculation number and their age.

The university requires a computerised system to support their student records. The university needs to be able to obtain a full list of its students, and a list of mature students (over 25 years old). For demographic purposes the university also needs to know the average age of its student population.

Analysis and Design

(4) Present a class diagram for the problem, and a short explanation for the model. Identify and consider any major decisions that you are making. What might we deem as other appropriate attributes for a student? What could be the attributes for the university?

(5) Produce a collaboration diagram showing a particular configuration of objects.

(6) Present collaboration diagrams and a short description to show the execution patterns for the following operations:

(a) the operation to display the full student list:
(b) the operation to display a list mature students over 25 years of age:
(c) the operation to display the average age of its students.

APPENDIX 8 QUESTIONNAIRE 1 IN CASE STUDY 1

Student Name:	Mode of study: full-time/part-time
Matriculation No. :	Sex: Male / Female
Programme of study:	

Please tick a box or fill in the blanks to answer the questions.

1. Did you study any relative subject(object-oriented related one) prior to taking this module? ☐ Yes ☐ No

2. You have learnt Java since last semester. Have you designed software system before programming? ☐ Yes ☐ No

If yes, please describe what you do.

3. How would you grade OOST concepts to understand at this stage?

< Very easy -- Very difficult >

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4. How relevant do you think the module in your programme?

< Not at all -- Very much >

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. How important would you grade the module in your studies?

< Not at all -- Very much >

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. What do you expect to learn from this module?

7. What do you find most difficult in programming with Java?

8. Do you think Interactive Multimedia learning applications for teaching and learning can improve your understanding with the topic? ☐ Yes ☐ No

If yes, please give details:

9. Would you be willing to participate in a focus group or interviews to discuss your experience of gaining an understanding of this subject? The meeting will last for no more than 1 hour.

If you are willing, please write down your e-mail address.

APPENDIX 9 QUESTIONNAIRE 2 IN CASE STUDY 1

Student Name:	Mode of study: full-time/part-time
Matriculation No. :	Tutorial time :
Programme of study:	

Section A

Please tick a box or fill in the blanks to answer the questions.

1. How much would you grade your understanding of Object-Oriented(OO) design with Java programming improved? (How much would you grade your capability of Java programming with object-oriented design approach improved?)

< Little -- Very much >

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. How easy/difficult would you grade OO concepts to understand now?

< Very easy -- Very difficult >

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3. How much would you grade IMM helped your understanding of OO design concepts?

< Little -- Very much >

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4. How much do you enjoy this module compared with others now?

< The least --- The most>

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. What 2 things did you find most difficult to understand?

1.
2.

6. What 2 things did you find easiest to understand?

1.
2.

7. What teaching method do you prefer?

☐ Traditional paper-based i.e. overhead slides or writing on a blackboard

☐ Using Interactive Multimedia(IMM) materials

8. What learning method do you prefer?

☐ Learning with traditional paper-based learning materials only

☐ Learning with IMM learning materials

☐ Learning with mixture of paper and multimedia-based materials

If you choose mixture of both, give details:

9. How did you use the IMM learning materials?

☐ During lectures and tutorials only

☐ As main resources to improve my understanding

☐ As reference materials to look up a topic

10. Should the IMM materials be both a teaching and a self-study guide? ☐ Yes ☐ No

11. Do you consider you could learn from the IMM materials independent without a tutor? ☐ Yes ☐ No

12. Did the IMM materials help you understand the OO concepts? ☐ Yes ☐ No

Please give details:

13. How much did the visualisation assist with your understanding of the abstract OO concepts?

☐ None ☐ Very little

☐ Some use ☐ Very beneficial

What part, if any, did the visualisation assist with your understanding of the OO concepts?

14. What type of questions in the IMM tutorial materials did you enjoy most?

☐ Multiple choice ☐ Filling-in

☐ Open questions only ☐ Open question with a task to do

15. What type of questions did you find most helpful to improve your understanding of object-oriented concepts?

☐ Multiple choice ☐ Filling-in

☐ Open questions only ☐ Open question with a task to do

16. When do you prefer to have hyperlinks in tutorial materials?

☐ Before answering questions ☐ After checking the model answer

☐ No hyperlink

17. Have you used the IMM materials at home? ☐ Yes ☐ No

18. What 2 things did you like most about the IMM materials for lectures and/or tutorials?

1. 2.

19. What 2 things did you like least about the IMM materials for lectures and/or tutorials?

1. 2.

20. What 2 things do you think to be improved or added about the IMM materials?

1. 2.

21. Any other comments?

22. Would you like to participate in a focus group or interviews to share your experience of studying SD module? The meeting will last for no more than 1 hour.

If you are willing, please write down your e-mail address.

Section B

This is to evaluate the Interactive Multimedia materials used in the beginning of this semester. For each statement please indicate whether you strongly disagree, disagree, neither agree or disagree, agree, strongly agree.

		strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
a	I found the IMM materials easy to use					
b	I found it easy to find the topic I want in the IMM materials					
c	I enjoyed using the IMM materials for *lectures*					
d	I enjoyed using the IMM materials for *tutorials*					
e	I enjoyed using the IMM *tutorial* materials for independent learning					
f	I enjoyed using the IMM *lecture* materials for independent learning					
g	I now have good understanding of OO concepts					
h	The IMM *lecture* materials were beneficial for my understanding of OO concepts					
i	The IMM *tutorial* materials were beneficial for my understanding of OO concepts					
j	The animations helped me understand the subject better					
k	The extra features (help, glossary) were helpful.					
l	I felt in control of my learning at all times					
m	I would like to use more IMM learning applications like this for *lectures*					
n	I would like to use more IMM learning applications like this for *tutorials*					
o	I would like to use more IMM learning applications like this for *independent learning*					
p	I will use the IMM materials when revising					
q	Hyperlink, if used, in the tutorial material was very useful for problem solving					
r	I feel that the ability to access information directly with hyperlink has helped me understand this subject better					

APPENDIX 10 SUMMARY OF THE FOUR GROUPS' CHARACTERISTICS

The characteristics of the four groups, classified by the changes in students' performance of the programming modules between the previous semester and this semester with IMM C++, are summarised, particularly in the areas of approaches to learning, approaches to using IMM courseware for learning, and their perceptions of learning with IMM.

Characteristics of Much Improved (MI) group

- **Characteristics of students**
  - Prior experience with IMM
  - Positive and open to a new approach for learning
- **Perceptions of their learning experience with IMM C++**
  - Positive; considered IMM C++ beneficial.
- **Approaches to learning (inferred from data collected)**
  - Approached learning to understand;
  - Used IMM C++ first to conceptualise C++ concepts and C++ programming process, then did programming tasks assessed;
- **Approaches to learning with IMM C++**
  - Used IMM C++ after lectures for learning or in a tutorial from the beginning;
  - Used it as a main learning material in conjunction with other paper-based ones. After constructing fundamental understanding of C++ with it and expanded their knowledge with other materials;
  - Used the T-IMM C++ and hyperlinks in tutorials;
  - Used IMM C++ for independent learning;
- **Learning outcomes**
  - Much improved learning outcomes;
- **Learning supports from IMM C++ (benefits of IMM C++ they perceived)**
  - Recognised the benefits of having IMM C++ for both teaching and learning; learning supports from the integration of IMM C++ in the learning environment.
  - Realised the benefits offered by the architecture of IMM C++ and hyperlinks;
  - Benefited from visual presentation from both teaching and learning.

Characteristics of Slightly Improved (SI) and Slightly Decreased (SD) groups

- **Characteristics of students**
  - More in SI had prior experience with IMM;
  - Less open and positive than MI group to a new approach for teaching and learning;
  - Some preferred to have a type of learning materials – either paper-based or IMM only;
  - Conscious of the assessment;
- **Perceptions of their learning experience with IMM C++**
  - Many considered IMM C++ satisfactory;
  - More critical in their learning with IMM C++ than the other two groups;
  - Two types of students: both did not change perceptions of IMM and approaches to learning;
    - Students with confidence – approached to learning as they preferred;
    - Students with low self-confidence – approached to learning as they used to; afraid of a new approach;
- **Approaches to learning (inferred from data collected)**
  - Some to understand;
  - Others to get good marks; focused on programming tasks in tutorials;
  - Some worked in a group even with IMM C++;
- **Approaches to using IMM C++**
  - Used IMM C++ after lectures for revision during the semester; less than MI group;
  - Some in SI group used it as the main learning material;
  - More in SD group used it as a reference material;
  - Some used the T-IMM C++ and hyperlinks in tutorials;
- **Learning outcomes**
  - Similar to their previous performance;
- **Learning supports from IMM C++ (benefits of IMM C++ they perceived)**
  - Benefits from the integration and architecture of IMM C++; less than MI group;
  - Benefited from visualisation.

Characteristics of Much Decreased (MD) group

- **Characteristics of students**
  - Most students with no prior experiences with IMM;
  - Negative to a new approach;
  - Inclined to use a type of learning materials;
- **Perceptions of their learning experience with IMM C++**
  - Some: negative to having IMM C++;
- **Approaches to learning (inferred from data collected)**

  - Personal problems: 7 students expressed personal problems in the semester;
  - Missed tutorials or lectures;
- **Approaches to using IMM C++**
  - Used it later in the semester or for the assignment;
  - Many did not use it for independent learning;
  - Some were even unaware that it was available for learning or realised it near the end of the semester; they considered it was for teaching only;
  - Did not use the T-IMM C++ much; no student was identified using both R-IMM C++ and T-IMM ++;
  - Many used IMM C++ in a group;
- **Learning outcomes**
  - Poorer performance compared with their marks in the previous semester;
- **Learning supports from IMM C++ (benefits of IMM C++ they perceived)**
  - Some: benefited from visualisation;
  - Benefits from IMM C++ were somewhat vague and general such as helped or eased understanding C++ concepts;
  - Some: realised benefits of IMM C++ in the learning context, but late in the semester;
  - Some did not consider IMM C++ either in lectures or for learning beneficial;

APPENDIX 11 QUESTIONNAIRE SURVEY 1 IN CASE STUDY 3

Student Name:	Mode of study: full-time/part-time
Student ID. :	Sex: Male / Female
Programme of study:	

Please tick a box or fill in the blanks to answer the questions.

1. How do you perceive C++ programming?

< Very easy	----------	----------	----------	Very difficult >
☐ 1	☐	☐ 3	☐ 4	☐ 5

2. How would you grade your understanding of C++ programming?

< Poor	----------	----------	----------	Excellent >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

3. Had you studied any relevant subject matter (Object-Oriented Software Design and Programming) prior to taking this module? ☐ Yes ☐ No

4. How would you grade your current understanding of Object-Oriented (OO) concepts?

< Poor	----------	----------	----------	Excellent >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

5. How difficult/easy would you grade OO concepts to understand?

< Very difficult	----------	----------	----------	Very easy >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. How much does the visualisation in lectures assist with your understanding of the abstract OO concepts?

   ☐ None ☐ Very little

   ☐ Some use ☐ Very beneficial

What part, if any, does the visualisation assist with your understanding of the abstract OO concepts?

7. How important do you consider Object-Oriented Software Design(OOSD) and Programming in your studies?

< Not at all	----------	----------	----------	Very much >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

8. How much do you enjoy OOSD modules?

<Very little-- Very much>
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

9. How many hours are you going to spend on EE2040A Object-Oriented Software Design and EE2037A Object-Oriented Programming Workshop?

- EE2040A Object-Oriented Software Design : ________________ per week .
- EE2037A Object-Oriented Programming Workshop : ____________ per week.

10. What would you expect to learn from these modules?

EE2040A Object-Oriented Software Design:

EE2037A Object-Oriented Programming Workshop:

11. What 2 things did you find most difficult to understand?

1.
2.

12. What 2 things did you find easiest to understand?

1.
2.

13. How difficult/ easy would you grade C++ builder tool to use (compared with MS-DOS based Borland used last semester if you used)?

<Very difficult -- Very easy>
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

14. How beneficial would you grade the graphical interface of C++ builder for OO programming?

<Very little --- Very much>
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

15. Did you take C++ programming module with Dr Kalganova last semester?

☐ Yes ☐ No

16. If not, have you used any Interactive Multimedia(IMM) learning materials for your studies? ☐ Yes ☐ No

If yes, please give details (i.e. used multimedia materials to study math at home).

17. How would you grade the IMM materials used last semester helped you understand C++ programming?

<Very little -- Very much>				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

18. Have you used the IMM materials for your assignments or independent learning last semester? ☐ Yes ☐ No

19. Have you used the IMM materials at home? ☐ Yes ☐ No

If yes, please give the reasons:

20. Do you think the IMM materials used in lectures this semester can improve your understanding of OOSD? ☐ Yes ☐ No

If yes, please give the reasons:

21. Would you like to use the IMM materials for your own studies (i.e. using them at home or via Intranet?) ☐ Yes ☐ No

If yes, please give the reasons:

22. Would you like to have more IMM materials for your lab sessions or independent learning? ☐ Yes ☐ No

23. What 2 things do you like most about the IMM materials in lectures?

1.
2.

24. What 2 things do you like least about the IMM materials in lectures?

1. 2.

25. What 2 things do you think to be improved or added about the IMM materials?

1. 2.

26. Please write 2 things you like most and least about the OO modules (i.e., teaching materials, tools used or teaching methods).

EE2040A Object-Oriented Software Design:

EE2037A Object-Oriented Programming Workshop:

27. Please write how the OO modules to be improved regarding teaching materials (IMM materials and other paper-based ones) and delivery methods.

28. General comment

29. Would you like to participate in a focus group or interviews to share your experience of studying OOSD? The meeting will last for no more than 20 minutes.

If you are willing, please write down your e-mail address.

APPENDIX 12 QUESTIONNAIRE SURVEY 2 IN CASE STUDY 3

Student Name:	Mode of study: full-time/part-time
Matriculation No. :	Programme of study:

Section A

Please tick a box or fill in the blanks to answer the questions.

1. How much would you grade your understanding of Object-Oriented (OO) design with C++/Java programming improved? (How much would you grade your capability of C++/Java programming with OO design approach improved?)

< Not at all	----------	----------	----------	Very much >
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2. How easy/difficult would you grade OO concepts to understand now?

< Very difficult	----------	----------	----------	Very easy>
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

3. How much do you enjoy the OOSD and OOPW modules compared with others now?

< Not at all	----------	----------	----------	Very much>
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

4. How much would you consider your initial expectations of the modules fulfilled now?

< The least	----------	----------	----------	The most>
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

5. Have you used the C++ IMM materials from last semester? ☐ Yes ☐ No

If yes, please give the reasons.

6. What 2 things do you find most difficult to understand in terms of OO software design and implementation?

1.
2.

7. What 2 things do you find easiest to understand?

1. 2.

8. What teaching method do you prefer?
   - ☐ Traditional paper-based i.e. overhead slides or writing on a blackboard
   - ☐ Using Interactive Multimedia(IMM) materials

9. What learning method do you prefer?
   - ☐ Learning with traditional paper-based learning materials only
   - ☐ Learning with IMM learning materials
   - ☐ Learning with mixture of paper and multimedia-based materials

If you choose mixture of both, give details:

10. How did you use the IMM learning materials this semester ?
    - ☐ During lectures and tutorials only
    - ☐ As main resources to improve my understanding
    - ☐ As reference materials to look up a topic

11. Should the IMM materials be both a teaching and a self-study guide? ☐ Yes ☐ No

12. Do you consider you could learn from the IMM materials independent without a tutor? ☐ Yes ☐ No

13. Did the IMM materials help you understand the OO concepts? ☐ Yes ☐ No

Please give details:

14. How much did the visualisation assist with your understanding of the abstract OO concepts?
    - ☐ None
    - ☐ Very little
    - ☐ Some use
    - ☐ Very beneficial

If it did, how did the visualisation assist with your understanding of the OO concepts?

15. What type of questions in the IMM lab-session materials did you enjoy most?
    - ☐ Multiple choice ☐ Filling-in
    - ☐ Open questions only ☐ Open question with a task to do

16. What type of questions did you find most helpful to improve your understanding of OO concepts?
    - ☐ Multiple choice ☐ Filling-in
    - ☐ Open questions only ☐ Open question with a task to do

17. Have you used the hyperlinks in lab-session materials? ☐ Yes ☐ No

18. Have the hyperlinks helped your understanding of the OO concepts? ☐ Yes ☐ No

If yes, how did the hyperlinks assist with your understanding?

19. When do you consider having hyperlinks in the lab-session materials could be most beneficial to assist your learning?
    - ☐ Before answering questions
    - ☐ After checking the model answer
    - ☐ Neither

20. Have you used the IMM materials at home? ☐ Yes ☐ No

21. What 2 things did you like most about the IMM materials for lectures and/or lab-sessions?

1.
2.

22. What 2 things did you like least about the IMM materials for lectures and/or lab-sessions?

1.
2.

23. What 2 things do you think to be improved or added about the IMM materials?

1.
2.

24. What 2 things did you like most about the OOSD and OOPW modules?

1. 2.

25. What 2 things did you like least about the OOSD and OOPW modules?

1. 2.

26. Any other comments?

27. Would you like to participate in a focus group or interviews to share your experience of studying OOSD and OOPW modules? The meeting will last for no more than 15 minutes.

If you are willing, please write down your e-mail address.

Section B

This is to evaluate the Interactive Multimedia materials used in the beginning of this semester. For each statement please indicate whether you strongly disagree, disagree, neither agree or disagree, agree, strongly agree.

		strongly disagree	disagree	neither agree or disagree	agree	strongly agree
a	I found the IMM materials easy to use					
b	I found it easy to find the topic I want in the IMM materials					
c	I enjoyed using the IMM materials for *lectures*					
d	I enjoyed using the IMM materials for *tutorials*					
e	I enjoyed using the IMM *tutorial* materials for independent learning					
f	I enjoyed using the IMM *lecture* materials for independent learning					
g	I now have good understanding of OO concepts					
h	The IMM *lecture* materials were beneficial for my understanding of OO concepts					
i	The IMM *tutorial* materials were beneficial for my understanding of OO concepts					
j	The animations helped me understand the subject better					
k	The extra features (help, glossary) were helpful.					
l	I felt in control of my learning at all times					
m	I would like to use more IMM learning applications like this for *lectures*					
n	I would like to use more IMM learning applications like this for *tutorials*					
o	I would like to use more IMM learning applications like this for *independent learning*					
p	I will use the IMM materials when revising					
q	Hyperlink, if used, in the tutorial material was very useful for problem solving					
r	I feel that the ability to access information directly with hyperlink has helped me understand this subject better					

APPENDIX 13 SUMMARY OF THE EMPIRICAL STUDY

Pilot study

A pilot study was designed to evaluate the IMM courseware (IMM OO), its architecture and design features, in supporting student learning with programming into an educational context. This study was conducted at Brunel University during two 3 hour tutorials (lab sessions) of the Object-Oriented Programming (OOP) module in week 10 of semester 1 of 2000/2001. Students who enrolled for the module were divided into two tutorial groups, and both tutorials were scheduled on the same day. IMM OO, its modification based on the feedback from the usability assessment, was integrated as part of the tutorial materials. In this study, only two versions of T-IMM OO, no-hyperlink and dynamic-hyperlink versions, were compared. These two versions were randomly installed on computers in the computer lab where tutorials took place.

At the time of this study, *Lecturer B* had already started to teach object-oriented concepts and programming in lectures, and she considered IMM OO suitable as part of the course materials. For the tutorials *Lecturer B* prepared paper-based programming tasks that required students to apply the concepts, message passing and objects, which students were expected to learn from IMM OO. IMM OO and the paper-based programming tasks were introduced to students as tutorial materials for the session. Before and after students used IMM OO for an hour and a half, a pre-test and post-test were performed by students. Both tests were prepared by *Lecturer B,* and each contained three types of questions with the same level of difficulties: one identifying objects, the second objects and messages, and the third message types and message passing process. Both tests were marked by *Lecturer B.* In addition, two questionnaires were answered by the students: one with the pre-test before using IMM OO to investigate student learning perceived with the module and the other afterwards to evaluate the usability of IMM OO. The main reason for the first questionnaire was to examine how students experienced their learning with the existing course materials, PowerPoint with animations embedded. It was important for two reasons. One was that IMM OO would be integrated into this module in the following year with which case study 3 was scheduled. Second was that the author and *Lecturer B* planned to develop IMM courseware for C++ programming (IMM C++), which would then be integrated into a programming module in the following semester. Case study 2 would be conducted in that environment. In addition, the PowerPoint materials assessed as part of the preliminary study, reported in Chapter 3, were the course materials of this OOP module. Students' learning perceived with the existing PowerPoint materials was expected to bring some useful insights for the design and integration of IMM courseware for student learning of programming. Comparisons could also be made with data from case study 3.

The pre-test and post-test results from the pilot study revealed that students' understanding of object-oriented concepts, objects and messages, significantly improved after using IMM OO. These were well reflected in their responses from usability assessment of IMM OO. Most students responded to their experience with IMM OO positively excluding two advanced students who considered IMM OO did not have enough information to suit their needs. Later, *Lecturer B* reported that in subsequent teaching it was easy to teach how to implement objects and messages in actual programming because of their learning experienced with IMM OO. She could refer to the visual examples in IMM OO, and students seemed to recall the visually presented concepts and came to understanding how they were implemented in programming easier than other concepts.

Case study 1

IMM OO was further developed based on the usability assessment results from the pilot study; the interface of IMM OO was slightly modified, i.e. icons and navigation, and more contents were added. Case study 1 was conducted at Napier University during semester 2 of 2000/2001. The aims of this study were in three areas: one evaluating learning effects of three different variants of T-IMM OO - no hyperlink, static hyperlink and dynamic hyperlink versions; the second assessing whether integrating IMM OO in lectures and tutorials supports student learning of the module as expected (see Chapter 4); and the third assessing whether integrating IMM OO in lectures and tutorials promotes interactions between students, and between students and teaching staff. In addition, this study tried to identify contextual factors affecting teaching and learning processes with IMM OO in the context.

IMM OO, presented in Section 4.5.2, was developed for lectures and tutorials for the first 6 weeks. *Lecturer N* desired to develop IMM OO for the whole semester, but this was not feasible at the time due to his workload. IMM OO was integrated into the curriculum with other paper-based learning materials co-authored by *Lecturer N* and another tutor, and a UML modelling tool. IMM OO was installed on the university Intranet to support learning. In the context it was used for teaching in lectures and for learning in tutorials. For case study 1, T-IMM OO was developed in three different variants: no-hyperlink, static-hyperlink and dynamic-hyperlink versions. With permission from *Lecturer N,* these three versions were assigned to the 5 tutorial groups. The main reason that *Lecturer N* allowed the use of the three different versions was IMM OO had search facilities built in it.

For the first 5 weeks lectures were delivered with R-IMM OO, and from week 2 to week 6 students used T-IMM OO in tutorials answering questions and doing tasks in it along with paper-based programming tasks. In week 4 and week 6, two tests were carried out. The aims were, primarily, to compare students' performance between three

T-IMM OO versions, and secondarily, to determine whether their performance became improved as a result of using IMM OO. Each test contained an object-oriented modelling task (designing a class and collaboration diagrams), and the tasks for both tests and model answers were prepared by *Lecturer N.* In addition to the two tests, several research methods were used to collect data. Firstly, two questionnaire surveys were conducted to ascertain how students' perceived their learning experienced with IMM OO. Secondly, observations were conducted by the author in tutorials and lectures to explore students' interactions with IMM OO, and with peers and tutors. Thirdly, IMM OO was programmed to create a tracking file in order to collect records of how students used IMM OO.

As reported in Chapter 3, *Lecturer N* had used Toolbooks to teach this module in the previous year. Comparing data from the preliminary study and the pilot study with ones from case study 1 could help determine benefits of the design and integration approach with IMM courseware and learning the effects of direct access to information as part of feedback (hyperlinks with questions and tasks).

The data from case study 1 revealed that dynamic hyperlink version of T-IMM OO (providing hyperlinks for direct access to related concepts in R-IMM OO after answering incorrectly or after open questions and design tasks) improved students' performance most effectively. The use of IMM OO in lectures encouraged students to revisit what had been taught in lectures either in tutorials or from their independent learning. In addition, the use of T-IMM in tutorials facilitated students to test their understanding with questions and tasks. Hyperlinks in T-IMM OO providing direct access to related information in R-IMM OO helped students correct their misconceptions. Students seemed to become better prepared for the following lecture and could understand and integrate new concepts taught in the lecture to their existing knowledge more easily.

Secondly, students' performance of the two tests revealed that using IMM OO in lectures and tutorials supported student learning. The analysis of the test results revealed that student learning between week 4 and week 6 improved significantly. In addition, students' perceptions of the subject matter improved when compared with the previous year students with Toolbooks. Thirdly, IMM OO in the context supported students' independent learning. They were able to find most of their own solutions for tasks or questions from IMM OO. In tutorials, questions from students to tutors were reduced, which provided tutors with more time to support students with difficult questions. Students' responses from interviews revealed that they felt more comfortable to ask questions to their tutor for two reasons. One was that they could use IMM OO to learn at their own pace in tutorials and find most of their own answers from it. This helped students gain some control over their learning and reduced their dependency on their tutor. The second was that as questions from students were reduced, they did not feel that they were holding other students up. An additional benefit of using IMM OO in tutorials discovered was that students' questions became more precise.

The last important finding was how much teaching staff's openness and learning supports affect students' approach to learning with IMM courseware.

Case study 2

Case study 2 was conducted at Brunel University from week 5 until the end of semester 2 of 2000/2001. Preliminary findings from case study 1 were incorporated to better facilitate student learning with IMM C++. The primary aim of this study was to investigate how students experience their learning of programming with IMM courseware in the educational context, and from analysing the data to determine the effects and benefits of the design and integration approach, presented in Chapter 4. In addition, this study and case study 3 aimed to further explore contextual factors and the characteristics of students affecting student learning with IMM courseware. The two studies also continued to investigate the learning effects of the design features - hyperlinks in T-IMM (the third hyperlinks version) and visualisation. IMM courseware (IMM C++), developed in collaboration with *Lecturer B*, was integrated into a programming module, Programming and Software Design (Pg & SD) 2 to support students' understanding of programming concepts; in particular to improve weak students' understanding. (Some students did not gain sufficient knowledge of C++ programming concepts from semester 1, which compounded difficulties of teaching the subject matter and it was hoped that integrating IMM courseware for both teaching and learning could remedy the situation.) To determine if the design and integration approach did facilitate students' learning as expected, the following areas were investigated: who benefited most (improvement in performance and perceptions of learning of C++ programming experienced), how students' approached learning with IMM C++, what benefits they gained and if and how these were related. To obtain in-depth understanding of student learning with IMM C++ in the educational context, interviews with students were conducted and questionnaires with open questions were filled in at three different stages: during the semester, at the end of the semester and in the following semester.

One of the main findings from this study was that IMM C++ integrated for teaching and learning enhanced and helped students' understanding of C++ programming concepts as expected. Weak students, whose performance with C++ programming in the previous semester had been poor, improved their academic performance in this semester; moreover, their perceptions of and interests in C++ programming improved. The second finding was that students who used R-IMM C++ for learning after lectures and T-IMM in tutorials improved their performance significantly. They also realised the benefit of having IMM C++ for both teaching and learning. An important benefit identified by the students was that when they used IMM C++ in tutorials or for independent learning after lectures, they could reflect in and recall the lecturer's descriptions. Another benefit realised was that using T-IMM C++ after lectures helped them test their understanding and correct their misconceptions through directly visiting related information in R-IMM C++. Because the content in R-IMM had already been taught with it in lectures, their learning experience became enhanced. Most results and findings from this study were already found in case study 1, but extensive qualitative data from interviews revealed how individual student experienced learning with IMM C++. Results and findings of this study are reported in Chapter 8.

Case study 3

Case study 3 was a follow-up study of case study 2. This study was conducted at Brunel University in semester 1 of the 2001/2002. The primary aim of this study was to continue to investigate how students experienced the learning of programming with IMM courseware from case study 2 and with data to determine if student learning was supported as discussed in Chapter 4. In addition, this study aimed to further explore the benefit offered by the design and integration approach for students and lecturers. Interviews with students and teaching staff were continued from case study 2, and questionnaire surveys and observations were conducted. Comparisons were made between data from this study and data from the pilot study which was conducted with the same module in semester 1 of 2000/2001 to determine whether and how positively or negatively students' perceptions were changed by using IMM courseware.

IMM courseware (IMM OO), used in case study 1 was integrated into 2nd year programming modules, Object-Oriented Software Design (OOSD) and Object-Oriented

Programming Workshop (OOPW) modules. IMM OO was used in lectures and tutorials for the first 7 weeks. From week 8, PowerPoint slides with animations embedded were used in lectures. With IMM OO and PowerPoint slides, paper-based materials, i.e. handouts and programming tasks, were used with programming tools. In addition, from the university Intranet and Internet students could gain access to IMM C++ and other internet course materials of the Pg & SD 2 module in the previous semester (case study 2). These two modules were designed to teach object-oriented design and programming with two different languages: Java and C++. Students from the Internet Engineering course took the module with Java and students from other Computing and Engineering courses used C++ for programming.

The module consisted of lectures, seminars and tutorials (lab sessions). In lectures, object-oriented design was taught mainly with IMM OO for the first 7 weeks (whiteboard was used for additional examples) and later object-oriented programming with Java and C++ with PowerPoint slides. In seminar, students did practical work with pen and paper, and in tutorials students used T-IMM C++, and C++ Builder and Java Builder for programming tasks. The majority of the students who enrolled in this module had taken the Pg and SD 2 module in the previous semester. Therefore, they had an experience of using IMM courseware for teaching and learning. The rest were either direct entry to 2nd year or elective students, most of whom neither had background knowledge of C++ programming nor prior experiences with IMM.

The design and integration approach, presented in Chapter 4, was also applied in this study; however, a few changes were made after reflecting on the results and findings from the previous case studies. In case study 2, it was found that whereas most students used R-IMM C++ for learning, many did not use T-IMM C++. Some were even unaware of its existence. The analysis of interview data with students suggested three possible reasons. In the previous semester, students were divided into several tutorial groups, and the module was delivered by teaching. In lectures *Lecturer B* suggested students to use T-IMM C++ in tutorials and even added a written instruction in paper-based tutorial materials. However, interviews with students revealed that many students did not try to use it. One of three main reasons identified was that teaching C++ programming started from week 5 and some students had already stopped coming to tutorials. The second reason was students' resistance to a new approach. The third was that some tutors did not encourage students to try T-IMM C++. To remedy this, students were encouraged, *forced* (*Lecturer B*'s description), to use T-IMM OO in the first tutorial.

One of the main findings from this study was an additional benefit of IMM courseware in the context; many students, especially new students, used IMM C++ for independent learning and gained a good understanding of C++ programming. Another finding concerned benefits which the teaching staff gained by integrating IMM courseware in lectures and tutorials, and for learning. *Lecturer B* did not need to repeat the same explanation for a concept in lectures because students came to understand it easily with visually enhanced presentation, and thus she could spend her time on more difficult concepts. Independent learning was supported by IMM courseware and students took some control of their own learning, which saved contact time with students for answering repeated questions. With IMM courseware integrated, the number of students waiting outside *Lecturer B*' office near coursework submission date or final exam was reduced significantly. The results and findings from this study will be reported in Chapter 8. The results from case study 2 and this study revealed that familiarity affected students' use of IMM. Introducing R-IMM in lectures helped students become familiar with it and they used it for learning.

APPENDIX 14 PAPERS PRESENTED AT CONFERENCES

- Short-paper presented at Innovation and Technology in Computer Science Education, June 2001, Canterbury UK.
- Full-paper presented at Progress 1, 2001, Hull UK.
- Short-paper presented at ALT-C, September 2001, Edinburgh UK.
- Short-paper presented at 'Design Education: A Dialogue Across Cultures', February 2002, Split Croatia

Short-paper presented at Innovation and Technology in Computer Science Education, June 2001, Canterbury UK

Using Interactive Multimedia for Teaching and Learning Object Oriented Software Design

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Object Oriented (OO) design and programming is an abstract and complex domain, and students have problems with understanding the concepts and applying them to the design of software systems. At Napier Nniversity, approximately 400 undergraduate students per year take Object Oriented Software Design (OOSD). There is a growing need to find a way to support students' learning. The question was what we could do to support large number of students with an abstract domain. The solution we came up with was using Interactive Multimedia (IMM) for learning and teaching the subject.

Key strengths of IMM are interactivity and visualisation. IMM can help students develop clear understanding of OO concepts such as objects, classes, and message passing through interactivity and visualisation.

Learning requires active thinking. Although the IMM materials will be initiated from a lecture or a tutorial, they are aimed to be self-directed learning materials. The materials should be able to encourage students to think actively in order to promote deep learning. Hyperlinks have been used to prompt internal question and reflection. Graphical representation is used to visualise OO design process from real world physical objects to software system built.

Research into students' learning using these features is needed in order to explore new design aspects with IMM to improve learning in higher education. Two different types of learning materials have been developed to support this research. One is a resource-oriented material which is similar to primary courseware (Mayes and Fowler, 1999) and will be initiated by a lecturer in a lecture. The other is a task-oriented material with embedded hyperlinks to the resource-oriented ones, and will be used in a tutorial. To investigate the effectiveness of hyperlinks in promoting cognitive interactivity, we test three types of hyperlinks, which are no hyperlink, static hyperlink presented as default and dynamic hyperlink appearing with tips when there is a mistake or incorrect answer made.

This poster will describe trials conducted at Brunel and Napier universities. The results and comparison made from the trials in terms of students' attitudes to IMM assisted learning and their performance will be presented along with findings about hyperlinks and visualisation in learning.

Reference

Mayes, J. T. and Fowler, C. J. (1999) Learning technology and usability: a framework for understanding courseware. Interacting with Computers, Vol. 11, No. 5, pp. 485-497

Full-paper presented at Progress 1, 2001, Hull UK.

Use IMM to improve your programming course

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Abstract: This paper reports first year students' experiences with multimedia-based learning for programming and its influence on students obtained from two case studies at Napier and Brunel universities. Engineering students at the universities have taken programming courses from their first year and many have showed difficulties in their learning. The main reason is that it is a very abstract domain, which means that both lecturers and students can have difficulties in explaining and understanding abstract concepts verbally. Considering the strengths of Interactive Multimedia (IMM), i.e. interactivity and visualisation, we decided to use it to improve students' learning.

An empirical study was planned and IMM materials were designed for this. A trial and two case studies were carried out from December 2000 to June 2001. The designed materials were integrated into the curriculum as a teaching aid and self-guided learning materials. The data gathered from the case studies indicated that many students felt the multimedia-based learning helped their understanding of the programming concepts, and some became very motivated in programming. Also, using the interactive multimedia materials for both teaching and learning enhanced students' learning experience. At last, we found educating both lecturers and students on what is multimedia-based learning prior to a course can increase its effectiveness.

1. INTRODUCTION

This story goes back to early 90'. A student encountered programming for the first time when she started "Computer Science" course in Engineering at a university. She did not have any prior experience with programming or even with a computer. The course was chosen with the belief that she would enjoy studying the leading technology and it would ultimately lead her to a bright and promising future. Well, what was waiting for her broke all of her illusion. One major problem she faced was that she simply could not understand programming. It seemed to her that the abstract concepts of programming were easy to some students when others including her had much struggle to understand what was going on with programming.

Another problem she had was that she could not get appropriate help from her tutor. The student says that she still remembers the puzzled look of a young lecturer who did not understand why some students had problems with programming. At that time she thought, 'Ok, you think programming is a piece of cake. But I don't. What I need right now is not a brainy lecturer who knows how to programme but one who understands my problem and can help me grasp the programming concepts.' At the end of the semester she found herself still struggling with programming. She decided to spend the whole summer vacation on studying programming and to change my course if she could not improve her understanding.

This problem faced by this female student 10 years ago is still a quite common problem, and many students face same or similar problems. Because of its abstract concepts, programming is not an easy subject to learn. 1st year students, particularly with low self-esteem or low motivation to learn, could be easily discouraged to learn this subject, which seems occurring at many universities in UK. Brunel and Napier universities, which are ex-polytechnics, also have encountered a similar problem with 1st year students with programming. As a solution, we decided to use IMM to support both teaching and learning the subject.

The remaining paper will describe the background literature taken - learning and IMM, brief description of the empirical study with the design features used and contextual environment. Finally, students' experience with IMM – factors affecting learning with IMM, their responses to the materials and multimedia-based learning – and lessons we learnt will be discussed.

2. LEARNING AND MULTIMEDIA

"Without love there is no learning". This comment made by David Mitchell at ALT-C 2001 conference had me pause and think about learning. You may have an experience being around a child asking many *why* questions because the child wants to learn things. According to Mitchell, we cannot really teach things to children unless they want to learn – meaning not only acquiring facts but also understanding the meaning. And many children stop asking *why* when a teacher starts to teach them. It seems as if the learning and teaching process that the current educational system supports does not always facilitate learning well. Probably, to solve this problem we should think teaching in terms of supporting learning and take teaching techniques accordingly. What is learning and how could we support it?

2.1 LEARNING

Learning concerns *thinking* - reasoning and reflection (1). Students should use reasoning such as deduction and induction, and reflection to construct their knowledge relating to their existing one. Learning should be meaningful more than memorising or reproducing knowledge presented by a teacher (2, 3). Entwistle et al. define this as 'deep learning', which means that in order to transfer outside information into internal knowledge, students must understand the information presented (2). They should conceptualise the information, make connections with already existing knowledge and have *deep understanding* of it. Mayes' learning framework (3), which is following, illustrates the internal activities effectively.

2.2 MAYES' LEARNING FRAMEWORK

This framework illustrates the internal process with three learning stages. The first stage is conceptualisation, which refers to the student's initial contact with a learning material. The second stage is construction requiring students build on the concepts learnt in the conceptualisation stage and refine their understanding by working on tests and examples. The third stage is for students to refine their understanding through dialogue and discussion.

Fowler and Mayes (4) have later modified the learning framework, illustrated in Figure 1, by extending the notion of dialogue into the three stages. This includes dialogues or learning conversations for clarification and confirmation at the conceptualisation stage, and dialogue for co-operation and collaboration at the construction stage. They also replaced the dialogue stage with the stage of 'identification' in which students reached a sufficient level of understanding to be able to relate to other conceptualisations and thus begin the process again. Fowler and Mayes (5) explain dialogue as the vehicle for conceptual movement.

2.3 INTERACTIVE MULTIMEDIA (IMM)

Many students have shown difficulties regarding their learning with abstract domains, and one of them is programming. The reason is that it is difficult to grasp abstract concepts as research shows that 65% is perceived visually (6). Like an old Chinese proverb "Seeing is believing.", visualising the abstract concepts can help students understand them. IMM has strengths for visualisation and furthermore, interactivity.

Multimedia with its combination of graphics, video, sound, animation and text has a number of potentially powerful characteristics which can be used to improve the learning process. First of all, by definition, it implies the use of combined media in presenting information which can be more effective than any single medium(7). The most appropriate medium for the required message can be selected, e.g. text for thoughts, graphics for spatial relations and animation for dynamic information. It also reinforces and supplements information through multiple representations. Secondly, multimedia allows simulation and visualisation which are particularly useful in areas that require understanding of complex, abstract, dynamic and microscopic processes (8). Moreover, multimedia allows users to take their own path through the material, and to build up their own knowledge. Enriched context with static and dynamic media enhances learning with the above strengths; however, the essence of multimedia is interactivity (9). Effective interactivity enhances the interplay between internal and external cognitive processes (10).

In order for multimedia to have a genuine pedagogical value, we should provide appropriate activities and design effective interactivity to support conceptual learning. With a sound design of IMM learning materials, they should be delivered in a way students can learn best.

3. LEARNING AND TEACHING WITH IMM : CASE STUDIES

IMM materials in these case studies were designed to teach and learn two programming modules at Brunel and Napier universities. As they were aimed to be used as the main courseware for the modules, the content was designed together with the module lecturers.

3.1 OVERVIEW OF THE CASE STUDIES

The IMM materials at Brunel University were used by 160 1st year undergraduate students for EE1036S Software Development with C++ module during the second semester of 2000/2001. The students had taken a basic programming course with C++ in the first semester, so the IMM materials were designed to teach and learn pointers, variables, structures and so on. The module was delivered by two lecturers, and the IMM materials were introduced by the second lecturer in week 4 and used till the end of the semester.

The IMM materials at Napier University were designed for CO12002 Software Development module and used by about 150 1st year students. The aim was to teach and learn software design with object-oriented approach using Java. They were used for the first 7 lectures and tutorials which continued about the first 4 weeks.

3.2 DESIGN CONTEXT

The following two are required to facilitate learning with IMM successfully. First is designing an effective material which supports the learning process, and next is using it appropriately. We consider that promoting cognitive interactivity within the material and supporting dialogue with it are the key issues for designing and using a learning material effectively. In order to achieve this, we designed two types of IMM materials, which were a resource-based material and a task-oriented one. The first aims to provide information as the main courseware and to be used in lectures. The latter is to provide tasks which enable students to apply the concepts they learnt in tutorials. As a consequence of the environment in which the materials are used, dialogue and collaborative work are supported and encouraged.

To promote internal interactivity, hyperlinks and animation are used - animation for visualising the abstract concepts in the resource-based material and hyperlinks supporting cognitive interactivity – cognitive dialogue and reflection – in the task-based one. Figure 1 illustrates how the proposed structure of design and use supports the modified Fowler and Mayes' learning framework (4).

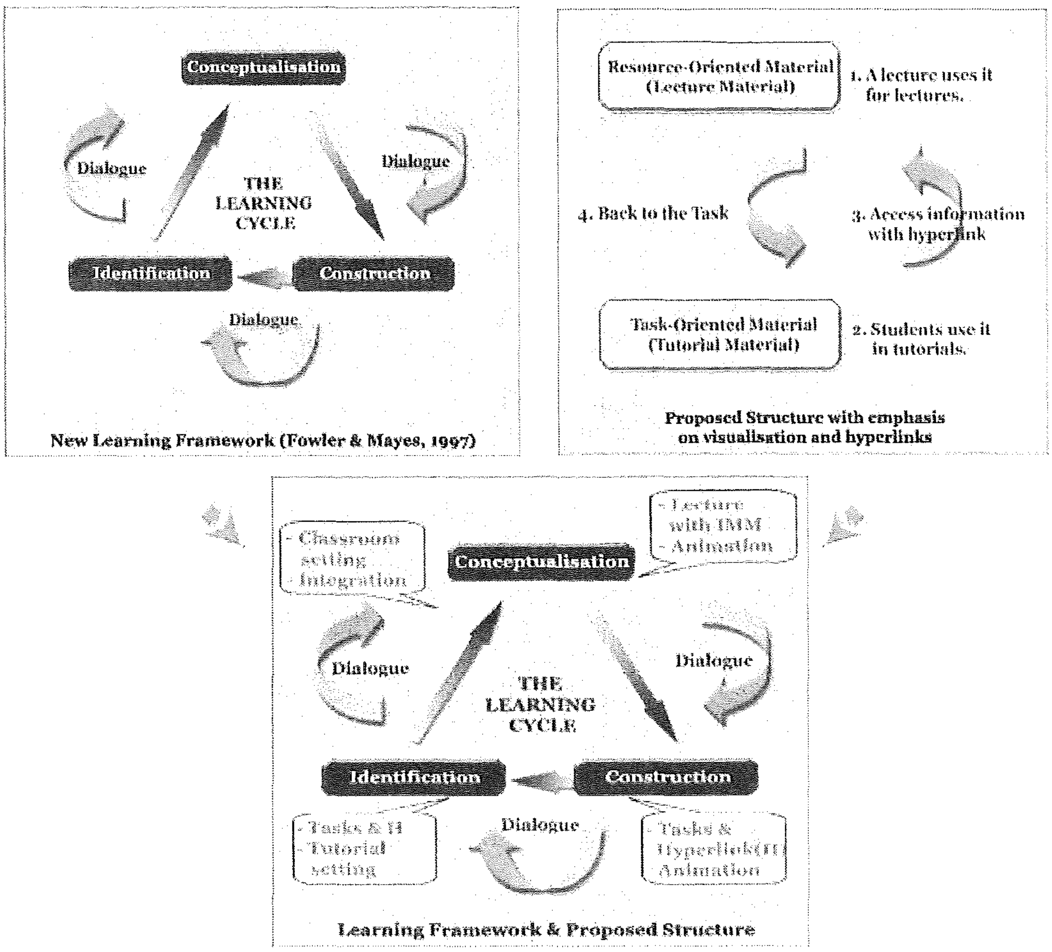

Figure 1 Learning framework and proposed design

3.3 STUDENTS' EXPERIENCES WITH IMM

We will describe students' experiences with IMM in three areas – Factors affecting their learning, their perception on the learning materials and their responses toward multimedia-based learning.

3.3.1 FACTORS AFFECTING STUDENTS' LEARNING

Like Prosser and Trigwell (11) suggest, students' prior experience, perception on learning influenced their learning. Furthermore, their learning was affected by their perception on multimedia-based learning and attitudes toward a new experience which is one of most strong barrier identified in this empirical study.

a. **Prior experience**: Students' prior experience with learning and with IMM influenced them to perceive the multimedia-based learning differently. Students with prior experience of using IMM responded more positively to using IMM and considered it very beneficial for their learning. On the other hand, students whose idea of learning was to be paper-based one got least benefit as they even did not attempt to use the materials at all.
b. **Perception on multimedia-based learning**: There is a notion that IMM can provide the control of learning to students. We found that many students and even some teaching staff interpreted this as students should learn on their own with IMM.
c. **Attitudes to a new experience**: Along with students' perception on learning, we found students' negative attitudes to a new experience problematic. Interviews with students revealed that some students were afraid of trying something new. Also, instead of perceiving that the IMM materials were provided to aid their learning, some felt that more workload was put into their direction.

An interview with a student summarises the factors influencing the above.
"….. In the beginning, I hated to use the multimedia materials. Without trying, I complaint to my friends outside the uni. And they said, "Try. If you don't like it, then delete it." So, I try it. I do not want to say it, but I liked it. I liked it very much. At home I went over the materials from the beginning to the end several times. It really helped me….."

3.3.2 STUDENTS' EXPERIENCE ON USING THE IMM MATERIALS

Students' attitudes to IMM became more positive as many realised the benefits it offered. There were few questions regarding how to use the materials during tutorials, and students felt easy to use them after trying a couple of times. Most students considered visualisation helpful to conceptualise the abstract concepts and hyperlink beneficial to correct their misconception. Many comments similar to the one below about animation were made student.
"…One thing is the animation…because the animation makes it very simple to

understand things ... like (pause) it makes you see what's really going on in the computer. And that makes it very useful, I think for me."

3.3.3 STUDENTS' RESPONSES TOWARD MULTIMEDIA-BASED LEARNING

Most students preferred to use IMM for both teaching and learning. Only some students wanted to use them for independent learning or teaching only. 71% of students at Brunel and 93% at Napier considered using IMM useful for their learning. It was identified that the lecturer, who had prior experience with IMM at Napier, designed the content more suitable for IMM use and delivered the material more effectively. This explains the different results. The following comment and conversation reveal how students perceived their learning with IMM for programming.

"...The multimedia material helped me understand the concepts a lot. But I don't know the basic concepts of C++ programming covered in the first semester. Multimedia should have been used from the first semester...."

Lecturer : "...This flowchart is not right. You should do.... But you seem to know pointers and structures and applied them in your programming...."
Student : "...Yes. Pointers and structures are easy concepts to learn. Isn't it right? But flowchart is very difficult to understand......" This may indicate that students got more benefits than they realised.

4. DISCUSSION

The data gathered from the case studies indicate that using IMM to teach and learn programming can bring benefits. It helped students conceptualise and apply the abstract concepts of programming in a problem-solving context. It also supported a lecturer, with a visual aid, to teach the abstract concepts which were difficult to explain verbally.

However, some obstacles were found with the multimedia-based learning. One is students' disinclination to learning the subject caused by their perceiving that they had more work to do with IMM than the paper-based learning and by their no attempt to use IMM for their learning. Our ultimate goal of bringing IMM into the curriculum was to help students who had difficulties with learning programming. Observation, survey and interview showed that some students, who needed help most, were the ones who declined to use the materials. How could we solve this problem? Perceptual change is required for these students to get benefits from using IMM. When their mind is against it, they cannot realise the true value of it.

Another problem identified was that using IMM required certain equipments such as a computer and CD-ROM driver or Internet connection. The materials were distributed via the university Intranet and Internet (only at Brunel university). Not all of the students had a computer at home although most had and the materials were always available at the universities. At Brunel some students felt frustrated as the IMM materials were the main courseware and there was not many additional materials provided.

In addition, teaching staff's inappropriate supports of the IMM materials were found as a problem. As caused by the misinterpretation about IMM offering one's control of their learning, some tutors considered that using the IMM materials replaced their teaching. It was not the intention of ours and we expected using IMM in tutorials to allow a tutor to pay more attention to the students who needed personal help.

To rid of those obstacles, we suggest that both students and tutors to be educated on how they could make most use of IMM in the beginning of a semester. It can help a tutor to better support students' learning with programming. It can also help students see the value of using IMM and as a result lead to their perceptual change toward multimedia-based learning. We should be aware that IMM is not the answer for learning and teaching but a means which has the potential to improve learning and teaching with programming. Therefore, we should use IMM to meet the needs of our students.

5. NEXT STEP

Having modified materials with the findings from the case studies, a new case study is designed and will be carried out to support students' learning with object-oriented software design at Brunel from October 2001. In this case study, IMM materials will be used for the whole semester for learning and teaching, and in the beginning a special session will be given to introduce IMM to the teaching staff and students. The materials will be distributed via Intranet, Internet, and CD-ROM, and additional paper-based materials and guidance will be provided if required.

REFERENCES

1. Jonassen D., Mayes T. and McAleese, R (1999), A Manifesto for a constructivist approach to technology in higher education in Duffy, T. Jonassen, D. & Lowyck, J. (Eds), *Designing constructivist learning environments*. Heidelberg, FRG: Springer-Verlag
2. Entwistle, N., Thomson, S. & Tait, H. (1992) *Guidelines for Promoting Effective Learning in Higher Education*, Centre for Research on Learning and Instruction, University of Edinburgh, Edinburgh
3. Mayes, J. T. (1995) 'Learning technologies and Groundhog Day', in Strang, W., Simpson, V.B. and Slater, D. (eds.), *Hypermedia at Work: Practice and Theory in Higher Education*, Canterbury:

University of Kent Press.

4. Fowler, C., and Mayes, T. (1997) Applying telepresence to education, in *BT Technology Journal* 14, 188-95
5. Fowler, C. J., and Mayes, J. T. (2000) Learning relationships from theory to design, *ALT-J* Vol. 7 No 3
6. Coorough C., (2001), Multimedia and the Web, Harcourt College Publishers
7. Laurillard, D. (1993), *Rethinking University Teaching: A Framework for the Effective Use of Educational Technology*, Routledge, London
8. Phillips, R. (1997) *The Developers Handbook to Interactive Multimedia: A Practical Guide for Educational Applications,* Kogan Page
9. McAteer, E and Shaw, R. (1995) *The Design of Multimedia Learning Programs*, The EMASHE Group University of Glasgow
10. Rogers, Y. and Scaife, M.(1997) How can interactive multimedia facilitate learning? *In Proceedings of First International Workshop on Intelligence and Multimodality in Multimedia Interfaces*, The Live Oak Press, Palo Alto, CA 94306-0036 123-142
11. Prosser, M. and Trigwell, K. (1999) *Understanding Learning and Teaching*, Open university press

Short-paper presented at ALT-C, September 2001, Edinburgh UK.

Using Interactive Multimedia for Teaching and Learning Object Oriented Software Design

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Students encountering the object-oriented paradigm for the first time often have problems with understanding the abstract concepts and applying them to software design. The complexity and dynamic nature of designing software system is a cause of this problem (Shinners-Kennedy, 1995). As many of our learning experiences are dependent on vision, visualisation with new learning technologies can bridge the gap between the abstract concepts, high level design and implementation. Some visual design tools, i.e. JBuilder, Visual C/C++, are introduced to offer an environment in which visually attractive programs can be developed (Spencer & Railton, 1995). However, they do not explain the underlying object-oriented concepts. Visualisation which can expose, explain and illustrate the fundamental principles of the object-oriented methodology should be added to using this visual design tools. Opportunities should also be given for learners to practice. As key strengths of interactive multimedia are visualisation, interactivity and multiple media, the technology can be a suitable technology to offer visualisation and interactive tasks.

This paper describes research into using interactive multimedia as a teaching aid and as self-directed learning materials through supporting dynamic linking and applying object-oriented concepts. This approach has the potential not just to enhance students' understanding of the abstract object-oriented concepts but also to improve their ability at problem solving through promoting reflection and active thinking.

To support this research an interactive multimedia learning application has been developed. It is intended that this will be used to support lectures and tutorials as well as independent study. A simple framework for university lecturers to employ for their teaching will additionally be described. To improve the cognitive development which, in this paper, means reflection and active thinking, we used hyperlinks and visualisation. Visual effects are aimed to illustrate the object-oriented concepts, and hyperlinks are embedded to improve students' self-enquiry learning skills(raising questions and finding answers internally) in a problem-solving task. To evaluate the effectiveness of hyperlinks in promoting cognitive development, we set experiments with three different types of hyperlinks, dynamic, static and no hyperlinks. Dynamic hyperlinks appear when students answer a question incorrectly. Static hyperlinks are displayed along with questions, and the last set of experiments show no hyperlinks between the two materials even though students can access both materials at the same time.

Experiments are to be carried out on BSc 1st year computing students at Brunel and Napier Universities. Findings will be presented focusing on the following areas- effects of integrating interactive multimedia learning materials into the curriculum, effectiveness of visualisation and hyperlinks, and students' attitudes.

REFERENCE

Shinners-Kennedy, D. (1995), Object-Orientation: Seeing Is Believing, In *proceedings of the 3rd Annual Conference on the Teaching of Computing*, Dublin, Ireland

Spencer, J. & Railton, A.L. (1995), Visualisation as a Teaching Tool in Computer Architecture, In *proceedings of the 3rd Annual Conference on the Teaching of Computing*, Dublin, Ireland

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Design for Teaching and Learning: Visualisation, Multiple Media, Interactivity

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Over the years fast changing technologies have brought many changes into areas and among them is education. Particularly multimedia with its powerful strengths, such as visualisation, multiple media and interactivity, attracted many to produce learning materials believing the technology has a potential to facilitate learning. However, it has been recognised that using a powerful technology alone cannot support learning, and in order to promote learning, materials are to be designed on sound pedagogy. Educational consideration should be given while designing the content of learning materials. Furthermore, we need to consider the learning environment in which the materials will be used.

The aim of this paper is to discuss design issues involved in designing educational multimedia materials to promote learning in higher education. While undertaking this research, it is recognised that in some areas using multimedia for both teaching and learning can facilitate learning more effectively. Multimedia can assist a lecturer to explain abstract domains, i.e., software design, with visualisation and multiple media, and help students understand the abstract concepts. It is also found that successful multimedia-based learning involves more than designing good educational materials. In the presentation the design issues of multimedia-based learning will be discussed. Finally, design guidelines and a contextual model for multimedia-based learning, derived from an empirical study, will be suggested.

APPENDIX 15 CD 'IMM OO & IMM C++

This CD contains the multimedia courseware used in the empirical study: IMM OO (R-IMM OO and T-IMM OO) and IMM C++ (R-IMM C++ and T-IMM C++).

REFERENCES

Aldrich, F., Rogers Y. and Scaife, M. (1998) 'Getting to grips with "interactivity": helping teachers assess the educational value of CD-ROMs', *British Journal of Educational Technology* 29 (4)

Barg, M., Fekete, Al. Greening, T. Hollands, O., Kay, J. and Kingston J. (2000) Problem-based learning for foundation computer science courses. Computer Science Education 10(2): 109-128

Baylor, A. and Ritchie, D. (2002) 'What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms?, *Computers and Education* 39 (4):395- 414

Baylor, A. and Ritchie, D. (2002) 'What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms?' *Computer and Education.* June 2002.

Beard, M. and Hartley, J. (1984) *Teaching and learning in higher education.* London: Harper & Row Ltd

Bednar, A., Cunningham, D., Duffy, T., and Perry, D. (1992) 'Theory into practice: how do we link?', in T. Duffy and D. Jonassen, (ed.) *Constructivism and the technology of instruction: A conversation*, New Jersey: Lawrence Erlbaum Associates

Biggs, J. (1978) Individual and group differences in study processes, British Journal of Educational Psychology, 48: 266—279

Biggs, J. (1989) 'Approaches to learning and to essay-writing', in R.R. Schemeck (ed.) *Learning strategies and learning styles*, New York: Plenum.

Booth, S. (1992) 'The experience of learning to program. Example: Recursion', in F. Detienne (ed.), *5-eme workshop usr la psychologie de la programmation*, Paris: INRIA, 122-145.

Boyle, T. (1997), *Design for multimedia learning*, London: Prentice Hall.

Brown, J., Collins, A., and Duguid, P. (1989) Situated cognition and the culture of learning. *Educational Researcher*, 18, 32-42.

Bruner, J. (1973) *Beyond the information given: Studies in the psychology of knowing.* New York: Norton.

Bryman, A. and Burgess, R. (ed.) (1994) *Analysing qualitative data.* London and New York: Routledge.

Byrne, P. (2001) The effect of student attributes on success in programming, In *proceedings of the 6th Annual Conference on Innovation and Technology in Computer Science Education*, June 2001, England.

Byrne, P. (2001) The Effect of Student Attributes on Success in Programming, In *proceedings of the 6th Annual Conference on Innovation and Technology in Computer Science Education*, June 2001, England. Cambridge: Prentice Hall.

Carroll, J. and Campell, R. (1988) *Artifacts as psychological theories: The case of human-computer interaction.* Technical Report RC 13454 (no60225). New Jersey: IBM Research Division, T. J. Watson Research Cancer

Chaiklin, S., and Lave, J. (1993) *Understanding practice. Perspectives on activity and context*. Cambridge: Cambridge University Press.

Chapman, N., and Chapman, J. (2000). *Digital multimedia.* John Wiley and Sons Ltd.

Clark, R. (1995) 'Authorware, multimedia, and instructional methods' in *Macromedia Authorware Version 3:Taking the Plunge,* Macromedia Inc. San Francisco CA.

Clarke, A. (1992) *The principles of screen design for computer based learning materials*, 2nd edition. Department of Employment Group, Sheffield

Collins, A., Brown, J. and Newman, S. (1988). 'Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics' in L B. Resnic (ed.), *Knowing, learning and instruction: Essays in honor of Robert Glaser*: 453 – 494. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cotton, B., and Oliver, R. (1993). *Understanding hypermedia: from multimedia to virtual reality*, Phaidon Press Ltd.

CSUP (1992) *Teaching and learning in an expanding higher education system: A Report of a Working Party of the Committee of Scottish University Principals.* SCFC, Edinburgh

Cunningham, D. (1992) 'Assessing constructions and constructing assessments: A dialogue', in T. Duffy and D. Jonassen, (ed.) *Constructivism and the Technology of Instruction: A conversation*, New Jersey: Lawrence Erlbaum Associates

Dann, W., Cooper, S., and Pausch, R. (2001) Using visualisation to teach novices recursion, *Proceedings of the 6th Annual Conference on Innovation and Technology in Computer Science Education.* England June 2001

Davis, H., Carr, L., Cooke, E. and White, S. (2001) 'Managing Diversity: Experiences Teaching Programming Principles'. In *Proceedings of The 2nd LTSN-ICS Annual Conference* , London.

Deegan, M., Lee, S. and Timbrell, N. (1996) *An introduction to Multimedia for academic use*. Oxford: Oxford University.

Dey, I. (1993) *Qualitative data analysis: A user-friendly guide for social scientists.* London and New York: Routledge.

Dix, A. Finlay, J. Abowd, G & Beale, R. (1998) *Human-Computer Interaction*, 2nd edition, Shinners-Kennedy, D. (1995), Object-Orientation: Seeing Is Believing, In *proceedings of the 3rd Annual Conference on the Teaching of Computing*, Dublin, Ireland

Duffy, T. and Cunningham, D. (1996) 'Constructivism: implications for the design and delivery of instruction', in D. Janassen (ed.) *Handbook of research for educational communications and technology*, New York: Simon & Schuster Macmillan.

Duffy, T. and Jonassen, D. (ed.) (1992). *Constructivism and the technology of instruction: A conversation.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Duffy, T., Lowyck, J. and Jonassen, D. (ed). (1993). *The design of constructivistic learning environments: Implications for instructional design and the use of technology.* Heidelburg, FRG: Springer-Verlag.

Durbridge, N.H. and Stratfold, MP (1996) 'Varying the Texture: A Study of Art, Learning and Multimedia'. *Journal of Interactive Media in Education*, 96(1)

Ellington, H., Percival, F. and Race, P. (1984) *Handbook of Educational Technology,* 3rd edition, London: Kogan Page.

England, E. and Finny, A. (2002) *Managing Multimedia.* (3rd) Addition & Wesley.

Entwistle, N. (1997) 'Contrasting perspectives on learning', in F. Marton, D. Hounsell and N. Entwistle (ed.) *The Experience of Learning*, Edinburgh: Scottish Academic Press.

Entwistle, N., & Ramsden, P. (1983) *Understanding Student Learning.* London: Croom Helm.

Entwistle, N., Thomson, S. & Tait, H. (1992) *Guidelines for Promoting Effective Learning in Higher Education*, Centre for Research on Learning and Instruction, University of Edinburgh, Edinburgh

Feldman, T. (1994) *Multimedia, blueprint.* Chapman & Hall.

Ford, N. and Ford, R. (1992) 'Learning in an 'ideal' computer-based learning environment', *British Journal of Educational Technology* 23 (3): 195-211

Fowler, C. and Mayes, J. (2000) Learning relationships from theory to design, *ALT-J* 7 (3)

Fowler, C., and Mayes, T. (1997) 'Applying telepresence to education', *BT Technology Journal* 14: 188-195

Gagne, R. and Briggs, L. (1979) *Principles of instructional design.* New York: Holt, Rinehart & Winston.

Gagne, R. and Merrill, M. (1990) 'Integrative goals for instructional design', *Educational Technology Research and Development*, 38 (1): 23-30

Gibbs, G. (1992) Improving the quality of student learning through course design. In '*Learning to effect*' Barnett, R. (ed.), Buckingham: SRHE and Open University Press.

Jenkins, T. and Davy, T. (2000) Dealing with diversity in introductory programming. LTSN-ICS, Edinburgh http://www.ics.ltsn.ac.uk/pub/conf2000/papers/jenkins.htm

Jonassen D., Mayes T. and McAleese, R (1993), 'A manifesto for a constructivist approach to technology in higher education', in T. Duffy, D. Jonassen and J. Lowyck (ed.) *Designing constructivist learning environments.* Heidelberg, FRG: Springer-Verlag

Kolb, D. (1984*) Experiential learning: experience as the source of learning and development*. Englewood Cliffs: Prentice Hall.

Kuperberg, M. (2002) *A guide to computer animation: for TV, game, multimedia and web*. Oxford: Focal Press.

Lakoff, G. (1987). *Women, fire, and dangerous things. Chicago*, IL: University of Chicago Press.

Laurillard, D. (1984). 'Learning from problem-solving', *Higher Education* 8:395-409

Laurillard, D. (1993), *Rethinking university teaching: A framework for the effective use of educational technology*, London: Routledge.

Laurillard, D. (1995) 'Multimedia and the changing experience of the learner', *British Journal of Educational Technology* 26 (3)

Laurillard, D. (1997) Styles and approaches in problem-solving. In F. Marton, D. Hounsell and N. Entwisle (ed.) *The experience of learning: Implications for teaching and studying in higher education*, 2nd edition. Edinburgh: Scottish Academic Press.

Laurillard, D. (2002), *Rethinking university teaching: A framework for the effective use of educational technology*, 2nd edition. London: Routledge.

Laurillard, D., Stratfold, M, Luckin, R., Plowman, L., and Taylor, J (2000) Affordances for learning in a non-linear narrative medium, *Journal of Interactive Media in Education*, Open University. http//:www-jime.open.ac.uk

Lave, J. (1988). *Cognition in practice*. Cambridge: Cambridge University Press.

Lave, J., and Wenger, E. (1991) *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Li, Z. and Drew, M. (2004) *Fundamentals of Multimedia*. Pearson Education.

Light, G. and Cox, R. (2001) *Learning and teaching in higher education: the reflective professional*. London: SAGE Publications.

Linington, J. and Dixon, M. (2001) Picturing program execution, *Proceedings of the 6th Annual Conference on Innovation and Technology in Computer Science Education*. England June 2001: 25 – 28

Marton, F. and Booth, S. (1997) *Learning and Awareness*. New Jersey: Lawrence Erlbaum Associates.

Marton, F. and Saljo, R. (1997) 'Approaches to learning' in F. Marton, D. Hounsell, and N. Entwistle, (ed.) *The experience of learning: Implications for teaching and studying in higher education*, 2nd edition. Edinburgh: Scottish Academic Press.

Marton, F., and Ramsden, P. (1988) 'What does it take to improve learning?', in P. Ramsend (ed.), *Improving Learning: New Perspectives*, London: Kogan Page.

Marton, F., Beatty, E. and Dall' Alba, G. (1993) 'Conceptions of learning, *International Journal of Educational Research*, 19: 277-300.

Marton, F., Dall'Alba, G., and Tse, L. (1992). Solving the paradox of the Asian learner. Paper presented at *the fourth Asian Regional Congress of Cross-Cultural Psychology*, Kathmandu, Nepal

Marton, F., Hounsell, D., and Entwistle, N. (1997) (ed.) *The experience of learning*, 2nd edition, Edinburgh: Scottish Academic Press.

Mayer, R. and Moreno, R. (2002) 'Aids to computer-based multimedia learning.' *Learning and Instruction* 12:107 – 119.

Mayes, J. and Fowler, C. (1999) Learning technology and usability: a framework for understanding courseware, *Interacting with Computers* 11: 485-497

Mayes, J. T. (1995) 'Learning technologies and groundhog day', in W. Strang, V. Simpson and D. Slater, (ed.), *Hypermedia at work: Practice and theory in higher education*, Canterbury: University of Kent Press.

McAteer, E and Shaw, R. (1995) *The design of multimedia learning programs*, The EMASHE Group, University of Glasgow

Merrill, D. (1992) 'Constructivism and Instructional Design', in T. Duffy and D. Jonassen (ed.), *Constructivism and the Technology of Instruction: A conversation*. New Jersey: Lawrence Erlbaum Associates.

Pask, G. (1976) Styles and strategies of leaning, *British Journal of Educational Psychology* 46(2): 128-148.

Perkins, D. (1992) 'Technology Meets Constructivism: Do they make a marriage?', in T. Duffy and D. Jonassen (ed.), *Constructivism and the technology of instruction: A conversation*. New Jersey: Lawrence Erlbaum Associates.

Perry, T and Perry, A. (1998) University students' attitudes towards multimedia presentations, *British Journal of Educational Technology* 29 (4)

Phillips, R. (1997) *The developers handbook to interactive multimedia: A practical guide for educational applications.* London: Kogan Page

Piaget, J. (1970) 'Piaget's theory', in P. Mussen (ed.) *Carmichael's manual of child psychology*, 3rd edition. John Wiley and Sons Inc.

Postema, M., Dick, M., Miller, J. and Cuce, S. (2000) Tool Support for Teaching the Personal Software Process, *Computer Science Education* 10 (2): 179-193

Price, R. (1991) *Computer-aided instruction: a guide from authors*. Pacific Grove California: Brooks & Cole.

Prosser, M. and Trigwell, K. (1999) *Understanding Learning and Teaching*, London: Open university press.

Ramsden, P. (1992) *Learning to teach in higher education.* London: Routledge.

Reigeluth (1983) *Instructional-design theories and models*. New Jersey: Lawrence Erlbaum Associates.

Resnick, L. (ed.) (1987) Learning in school and out. *Educational Research*, 16: 13-20

Riding, R. (1996) *Learning styles and technology-based training*. University of Birmingham.

Riding, R. and Cheema, I. (1991) Cognitive styles. *Educational Psychology* 11: 193-215

Rogers, Y. and Scaife, M. (1997) How can interactive multimedia facilitate learning? *In Proceedings of First International Workshop on Intelligence and Multimodality in Multimedia Interfaces*, The Live Oak Press, Palo Alto, CA

94306-0036 123-142

Rogoff, B. and Lave, J. (ed.) (1984) *Everyday cognition: Its development in social context*. Cambridge, MA: Harvard University Press.

Rothkopf, E. (1970) 'The concept of mathemagenic activities', *Review of Educational Research*, 40: 325-336.

Saljo, R. (1979) 'Learning in the learner's perspective. Some commonsense conceptions', Internal Report, Department of Education, University of Gothenburg No. 76

Saljo, R. (1984) 'Learning from reading', in F. Marton, D. Hounsell and N. Entwistle (ed.) *The experience of learning*, Edinburgh: Scottish Academic Press.

Scaife, M., Rogers, Y. (1996) External cognition: how do graphical representations work? *International Journal of Human-Computer Studies* 45: 185-213

Shinners-Kennedy, D. (1995), Object-orientation: seeing is believing, In *proceedings of the 3rd Annual Conference on the Teaching of Computing*, Dublin, Ireland

Sooriamurthi, R. (2001) 'Problems in Comprehending Recursion and Suggested Solution', *Proceedings of the 6th Annual Conference on Innovation and Technology in Computer Science Education*. England June 2001: 25 – 28

Soper, J. B. (1997) Integrating interactive media in courses: The WinEcon software with workbook approach. *Journal of Interactive Media in Education*. 1997(2)

Spiro, R. (1988). *Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains* (Tech. Rep. No. 441). Champasign, IL: Centre for the Study of Reading.

Steinmetz, R. and Nahrstedt, K. (1995) *Multimedia: computing, communications and applications*. London: Prentice Hall PTR.

Suchman, L. A. (1987) *Plans and Situated Actions*. Cambridge: Cambridge University Press.

Thalmann, D. (1990) *Book 1: Scientific visualisation & graphics simulation*. John Wiley & Sons LTD.

Toolbook (SumTotal) http://www.sumtotalsystems.com/toolbook/

Vetere, F. and Howard, S. (1999) 'Redundancy effects in instructional multimedia system' in M. Sasse and C. Johnson (ed.) *Human-Computer Interaction-INTERACT'99*. IOS Presss.

Wheeler, D. (1998) *Rome-Graphical modelling tool for object oriented design*, Edinburgh, Napier University of Edinburgh

Wheeler, D. (1998) *Rome-Graphical modelling tool for object oriented design*, Edinburgh, Napier University of Edinburgh

Wills, G. B., Davis, H. C. and Cooke, E. C. (2004) Paired Programming for Non-Computing Students.. In *Proceedings of LTSN-ICS Fifth Annual Conference*, Ulster, UK.

Wittgenstein, L. (1953) *Philosophical investigations*. New York: Macmililan.