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Technology and the improvement of mathematics education at the tertiary level

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Technology and the Improvement of Mathematics Education at the Tertiary Level

Elahe Aminifar

B.Sc. Pure Mathematics, M.Sc. Applied Mathematics

A thesis submitted in partial fulfilment of the
requirements for the degree of

Doctor of Philosophy

School of Mathematics and Applied Statistics
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December 2007

Certification

I, Elahe Aminifar, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Mathematics and Applied Statistics, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Elahe Aminifar

21 December 2007

Dedicated to

My dear Javid who is the inspiration for my life and my study. His love, friendship and support has enabled me to keep the home fires burning through it all. Thank you Javid from the bottom of my heart for being there for me.

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Abstract

In recent times, technology is being used more and more in a variety of educational endeavours. This thesis considers the use of technology in the improvement of teaching and learning mathematics in higher education. In particular, it addresses, through three case studies, specific technological solutions to two well documented educational problems: the knowledge gap between secondary school and university level mathematics and how to provide higher level, honours or postgraduate, mathematics offering despite low student numbers.

A literature review provides the context of the problem and an overview of previous attempts at solving this difficulty.

The first case study addresses a common problem concerning students entering university from high school. It has been reported that students who enter university have insufficient mathematics knowledge and skills to take first year mathematics subjects and hence provide a sound mathematical foundation for other subjects. In this study at the University of Wollongong, video learning resources, predominantly worked solutions, have been developed to assist Engineering students in a first year mathematics subject. The four-stage evaluation model of Alexander and Hedberg (1994) was used to determine the effectiveness of the resources involved at each of the stages: *Design*, *Development*, *Implementation* and *Institutionalisation*. Evaluation addresses both the production methods and the learning outcomes. A mixed methodology combining surveys, interviews, and document analysis, was used to triangulate evaluation results at each of the four stages.

In 2006, two different technologies were used to produce video resources for a limited number of mathematics questions. In the first instance this was to determine the ease of production and the students' preferences for the resources. Following this trial, a set of video resources which covered all the topics taught during the first four weeks of the teaching session was developed. These resources were used to examine whether or not they could be used to bridge the gap from high school to university. Analysis indicated

that the resources were used by students whose mean baseline performance was lower than non-users ($t_{74} = 2.18$, $p = 0.033$). In week four the results of Basic Skills Test 2 revealed that students who used the resources improved more than those who did not ($t_{72} = 2.43$, $p = 0.018$), however, catching-up on fundamental mathematical skills was insufficient for there to be an impact on the final results in the subject. Surveys in the middle and at the end of the teaching session showed that students found the video resources were useful in helping them to learn and understand mathematics. Consequently, a set of video resources that covered all mathematics topics in the subject was developed for incoming students in 2007. To ascertain the impact of these resources, two cohorts of students were examined: students from 2004 with no resources and students in 2007 with a complete set of resources. Having established that baseline performance was the same, the students with resources were found to have improved their performance in all assessment tasks compared to students without resources: Basic Skills Test 2 ($t_{390} = 3.14$, $p = 0.002$), assignments ($t_{456} = 2.80$, $p = 0.005$), quizzes ($t_{456} = 3.49$, $p = 0.001$), examination marks ($t_{456} = 3.03$, $p = 0.003$), and final marks ($t_{446} = 2.38$, $p = 0.018$), except in the Mid-Session Test ($t_{467} = 0.65$, $p = 0.519$). The failure rate fell significantly in 2007 compared to the years between 2000 and 2006 ($Z = 2.10$, $p < 0.05$). Students' surveys suggest that while the primary gains have been in algorithmic learning, students consider they have better understanding of concepts. The final stage of institutionalisation reveals that the university has adopted and further extended the approach for the development of mathematics learning resources across disciplines.

The second case study addressed the use of two-way communication technologies for teaching and learning for geographically dispersed students at the tertiary level and in particular, for mathematics. To do this, the author of this thesis worked in an apprenticeship model with the guidance of the Manager of Learning Facilities and Technologies at the University of Wollongong to compare a selection of Real Time Communication (RTC) technologies using several criteria. These were based on the needs of teachers and students, the institutional infrastructure and the literature. As there are a variety of Real Time Communication (RTC) technologies, a two-stage evaluation was adopted. In the first stage, a list of RTC technologies was composed based on criteria found in advertising and promotional materials. In the second stage, each of the short-listed RTC technologies was trialled to determine their effectiveness and efficiency in teaching and learning. At the end of this case study, one of the RTC technologies, which provides multiple video and audio tracks of all participants as well as application sharing such as shared desktop and whiteboard, namely Access Grid, was installed and trialled.

With two other universities, also funded by the International Centre of Excellence for Education in Mathematics (ICE-EM), the opportunity arose for the third case study focussing on the question, 'How do universities provide a wide range of subjects to honours and upper level students when numbers of mathematics students and staff are small?'. The aim of installing a room-based node on the Access Grid was to teach and share the mathematics and statistics subjects with other Australian universities which had installed a room-based node. Three lecturers and eight students were interviewed and surveyed to evaluate the use of the Access Grid in teaching and learning these subjects. The lecturers and the students were tolerant of many technical failures, expecting them as part of the process of introducing new technology and recognising the opportunity provided by sharing classes. Two issues were identified: the need to train staff in the use of new pedagogical approaches and the fact that lecturers did not necessarily perceive the communication difficulties experienced by their students.

The thesis concludes with a look to the future of technology in mathematics education and makes recommendations for embedding video resources within subjects in the other disciplines. Recommendations are also made for the use of synchronous technology such as Access Grid in teaching and learning.

Publications

The following presentations and publications have been emerged from this thesis so far.

Paper in a Refereed Journal

1. Aminifar, E., Porter, A., Caladine, R. & Nelson, M. I. 2007, 'Creating Mathematical Learning Resources - Combining Audio and Visual Components', *ANZIAM Journal (EMAC2005),* vol. 47, pp. C934-C955.

Papers in Refereed Conference Proceedings

1. Aminifar, E., Caladine, R., Porter, A. & Nelson, M. I. 2007, 'Beyond Videoconference: Increased Functionality to Enhance Media-Rich Interactions in Teaching and Learning', in *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*, Québec City, Canada.

2. Aminifar, E., Caladine, R., Porter, A. & Nelson, M. I. 2006, 'Online Solutions to Mathematical Problems: Combining Video, Audio and Stills on the Web', in *Proceedings of World Conference on E-Leaning in Corporate, Government, Healthcare, and Higher Education,* Hawaii, USA.

3. Caladine, R. & Aminifar, E. 2007, 'The Future of Real Time Communication in Online Learning', in *Proceedings of 2007 Information Resources Management Association International Conference, 18th Annual IRMA International Conference,* Vancouver, Canada.

4. Porter, A., Caladine, R., Nelson, M. I., Aminifar, E. & Williams, G. 2007, 'Access Grid Rooms: The Plan, the Reality', in *Proceedings of Fourth East Asia Regional Conference on Mathematics Education,* Penang, Malaysia.

Papers in Conference Proceedings

1. Aminifar, E., Porter, A., Caladine, R. & Nelson M. I. 2006, 'Evaluation of Using Technology for Teaching and Learning Mathematics', *8th Iranian Mathematics Education Conference (IMEC-8),* Shahrekord, Iran.

2. Aminifar, E., Porter, A. & Caladine, R. 2005, 'Evaluation of Web Conference and Collaboration Tools for Teaching Mathematics and Statistics', *International Statistics Institute Conference,* Sydney, Australia.

3. Aminifar, E., Porter, A. & Caladine, R. 2004, Teaching Mathematics with Information and Communication Technologies, paper presented at the 2004 Research Methods, Statistics and Finance Conference, University of Wollongong, Australia.

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Chapter 1

Introduction

1.1 Technology and Education

Modern technologies have already shown their usefulness in providing a new approach to mathematics education, and are well on their way to becoming an essential and indispensable part of the educational experience. Today's students expect information and communication technologies (ICTs) to be part of their learning experience. Technologies also provide opportunities for flexibility in learning, a flexibility which is required by the many demands on students' time. ICTs, however, represent a substantial departure from the traditional ways of teaching mathematics. Thus, effective teaching and learning with them is a challenge that confronts teachers of mathematics in higher education in Australia and many other countries. If this challenge can be effectively met, the benefits will be in improved effectiveness and efficiency of teaching and learning for the many students undertaking mathematics or mathematics related subjects.

1.2 The Problem

Compared to some other disciplines, mathematics is old, yet it is a fundamental component of many other disciplines like science and engineering. There is a well-established tradition of teaching mathematics that contrasts sharply to the youth of information communication technologies (ICTs). Traditionally, mathematics has been taught in classrooms using chalk and talk. Quite apart from their youth appeal, ICTs have the potential to substantially improve teaching and learning outcomes and indeed, they are currently used to facilitate student learning in many disciplines and universities (Oldknow & Taylor 2000; Cooner 2004; Fitzallen 2005). The challenge for those who design learning and teaching, however, is to ensure that ICTs do this, rather than simply becoming the latest in a long line of possibly engaging but ultimately impractical teaching fads.

Perhaps the greatest challenge to those who teach mathematics to science and engineering students is the mismatch of mathematics skills. Many students arrive at university with mathematical knowledge and skill levels considerably lower than those required by the subjects they take. One way of attempting to solve this problem is through the use of ICTs.

1.3 Objective and Purpose

The general objective of the present research is to examine ways to improve mathematics education through the use of technology. In order to do this, it aims more specifically to answer the questions:

- Can video learning resources be used to support students’ learning at the tertiary level mathematics course?
- How effective are video learning resources in improving learning outcome such as understanding, confidence and motivation in mathematics?
- How can resources be developed such that the processes are sustainable and likely to be adopted by other staff?

- What Real Time Communication technologies are available or emerging for teaching and learning mathematics?
- How can Real Time Communication technologies be used for teaching and learning mathematics?
- How has Access Grid technology been applied to mathematics education at university level?

There are three challenges relating to this:

- the mismatch in mathematics knowledge and skills between those that students bring to university and those required of them to successfully complete first year and later subjects,
- locating, accessing and using suitable technologies for teaching and learning mathematics and
- providing a sufficient range of subjects for honours and higher level mathematics students in an environment where student numbers are small.

1.4 Approach and Methodology

Three case studies of different uses of technology in teaching and learning mathematics form the basis of this exploration:

- the use of video learning resources to support students' learning,
- a comparison of some Real Time Communication technologies in teaching and learning and
- an examination of the development of an Access Grid room to facilitate collaboration, research, teaching and learning mathematics at Australian universities.

The first case study addresses the problem of the decline in mathematical skills of students entering university and wishing to undertake a mathematics dependent university course such as science or engineering. Several different approaches to the improvement of learning outcomes in mathematics have been tried in different parts of the world. Innovations developed and implemented by others are discussed and an argument made for the development of a suite of video learning resources. This case study focuses on a first year mathematics subject that had been designed to improve students' basic mathematical skills and thus equip them for higher-level science, engineering and mathematics subjects. The subject included an assessment regime in which students' mathematics basic skills were tested in the first and fourth weeks of the teaching session as well as in the middle and at the end of the session. This provides a highly visible indication of any changes in students' performance.

Literature on the evaluation of educational technology was reviewed and an approach to evaluation was selected to evaluate the impact of the video resources on students' learning. As the video resources were delivered as part of the online component of the subject, the display of mathematical symbols was a major technical problem that had to be solved. Several existing solutions were evaluated as unsuitable for one of several reasons. The vision was to develop learning resources that included representations of the process of solving mathematical problems. A critical element of the learning resources was that they were to display the line-by-line or character-by-character development of the solution. One of the objectives of this research was to find a production method that was simple enough for teaching staff to use with minimal training and yet sufficiently robust to result in high-quality video learning resources.

A suite of video resources was developed and a limited number of them used in a trial in 2006. After the success of the trial, a more complete set of video resources was developed and deployed in the 2007 offering of the subject. Two different production methods were used and evaluated from the perspective of ease of production and impact on learning outcomes.

The second case study involved the researcher working with the Manager of Learning Facilities and Technologies at the University of Wollongong to compare the educational potential of Real Time Communication (RTC) technologies. Many organisations and universities use RTC technologies for business communications, training, teaching and learning. Some of them are mature and have been used for many years, while others suffer shortcomings that indicate that they might be immature and have yet to develop into tools that are appropriate for the improvement of teaching and learning in higher education. A selection of popular RTC technologies was compared using a range of criteria and recommendations were made to the university regarding the adoption of them.

The third case study focused on a project of the International Centre of Excellence for Education in Mathematics (ICE-EM) in which several Australian universities were funded to install room-based nodes on the Access Grid. The Access Grid is a Real Time Communication Technology that provides a particularly rich experience for participants. In room-based nodes, participants see multiple video images from other room-based nodes and three or four cameras in the room capture images of them. They enjoy full two-way audio and have the capability to collaborate on computer files and application sharing.

The ICE-EM project was developed to address a problem in mathematics education. At the higher undergraduate levels or at honours level, many Departments of Mathematics have small numbers of students who wish to undertake a wide range of mathematics and statistics subjects. This leads to two shortcomings: small class sizes and in some cases a mismatch between what students want to study and what is on offer at their university. The project proposed to use the Access Grid to enable effective teaching between universities. In this way, students at one university could enrol in subjects at another. Rather than travel to the other university, they could use the Access Grid to attend. In this case study, the technology and functions of the Access Grid are detailed and the first three sessions of teaching with it are evaluated.

1.4.1 Evaluation Framework

In order to ensure the future success of any innovation, its impact must be evaluated. In the case of new technologies used in the teaching and learning of mathematics, their impact on student learning outcomes must be evaluated. In addition, new technologies must also be suitable for the topics which are taught. For example, in these subjects the technologies will need to represent mathematical symbols, so issues of topic suitability must be part of the evaluation of the proposed technology. To maximise the return on the time, money and energy invested in such innovations, they should also be suitable for other disciplines across the university. This is another aspect which needs to be evaluated.

Innovators, educators and researchers, based on their needs and the nature of their innovations have used different models of evaluation. Often models of evaluation have four stages (Alexander & Hedberg 1994; Davidson & Goldfinch 1998; Bastiaens, Boon & Martens 2004), ending with a stage in which the innovations are implemented at the organisational or university level. In this study, Alexander and Hedberg's (1994) evaluation model, which consists of four stages: *Design, Development, Implementation* and *Institutionalisation*, was adopted because its four stages are particularly appropriate to reflect the stages in each case study.

In the design phase of the first case study, there was a requirement to recognise the precise mathematics topics in which students needed video resources. In the development phase prominence was placed on evaluating and hence selecting an appropriate technology for the development of the video resources. To recognise how the video resources impacted on learning outcomes, the implementation and development phases were evaluated. Finally, the potential for use in other parts of the university was evaluated. For example, at the end of the first case study, attention was placed on discovering whether the video resource production method have been adopted by other users or disciplines.

1.5 Overview of the Thesis

The use of technology in education should be guided by those needs that technology has the potential to fulfil. Clearly technological know-how is not sufficient. Background knowledge in the specific field of education is essential. It affords the opportunity to better evaluate the success or failures of suggested solutions to the problems. For this reason, the thesis begins with an exploration of the issues in mathematics education which provide the context for the present research.

Chapter 2 documents the challenges of teaching and learning mathematics at tertiary level and the approaches taken by others in addressing them. The chapter examines:

- the decline in mathematics backgrounds of students seeking to undertake tertiary mathematics,
- support provided by universities for students as they make the transition to university life and more specifically to university mathematics,
- different types of outcomes of mathematics education,
- theoretical approaches used to describe how mathematics learning takes place and
- reports in the literature of approaches that have been tried to improve mathematics learning outcomes.

Mirroring worldwide findings, the context for the first case study is established in Chapter 3. At the University of Wollongong, an introductory mathematics subject, which is problematic in terms of high failure rates, is examined in terms of:

- the gap between assumed and recommended prerequisite knowledge,
- the curriculum and pedagogical techniques,
- the assessment structure,
- the transition programs that are available to assist students,
- other forms of learning support available to students,
- an analysis of entry level skills and
- student evaluations and interviews with lecturers.

Drawing on reports, interviews and student evaluations, a case is made for the development of video resources to support learning. This leads to the search in Chapter 4 for a framework for evaluating the processes of producing the video resources and the impact of the video resources on learning outcomes. The literature review is extended to examine the use of video based resources to enhance mathematics learning. The literature review, together with the experience of the researcher as a teacher at university level, guides the design and development of the video learning resources. A preliminary discussion of technologies for the production of video resources is undertaken, followed by the design, development and documentation of the two different production processes. Comparative evaluation of the two techniques of production is undertaken, with an exploration of the adequacy of the video resources in terms of their technical properties including: audio, visual and other quality aspects. Following an evaluation of the quality of the video resources, student evaluations are used to assess the nature of the improvements in learning outcomes.

The work in Chapter 5 addresses evaluation of the development phase of the learning resource research. Rather than produce an entire suite of resources and then evaluate; a subset of resources was developed and trialled. It was important to identify suitable production technologies, but it was equally important to establish whether or not the resources were likely to have a positive impact on student learning. The performance of students in Basic Skills Tests before and after the use of resources allowed comparison of the performance of users with non-users. It also allowed the researcher to identify whether additional resources were required as well as to identify which topics were warranted.

With trials complete, and suggesting that students who initially performed poorly chose to use the video resources and had greatest gains, video resources were developed for all topics in a 100 level (first year tertiary) calculus subject for engineering students. The focus of Chapter 6 is on the evaluation which followed the introduction of a complete set of video resources. Specifically, the evaluation involves:

- examination of the impact of video resources on students' learning by comparing performance outcomes in skills tests, examinations, continuous assessments and final grades for two cohorts of students, those who had no video resources and those who did have resources;
- examination of the nature of students' understanding and learning associated with the use of the videos with reference to the cohort of students who had access to video resources;
- use of survey data to compare students' evaluation of the video resources with other forms of learning resources and
- use of survey data to determine where additional learning resources were needed to promote students' learning and understanding.

The analysis of the data provided recommendations to improve the set of learning resources for the next time the subject is taught.

Evaluation of technologies is a crucial part of exploring what technologies a university will adopt and how those technologies can be used, and often this predates the adoption by academic staff. The case study of Real Time Communication technologies focuses on the preliminary selection and trial of the technology within a university setting.

Chapter 7 examines how Real Time Communication (RTC) technologies such as videoconferencing, Video Chat, Web Conference Applications (WCAs) and Access Grid that currently are in use at institutions can be applied to learning and teaching. The evaluation of these technologies involved a three-stage evaluation strategy. In the first stage, a list of criteria was developed, based on the requirements of university teachers and learners, the university infrastructure and the literature. In the second stage a list of appropriate RTC technologies was chosen by comparing the criteria against advertising, promotional materials and specifications. A trial of each short-listed RTC was conducted in the second stage to check their ease of use, effectiveness and efficiency in implementing the features considered important to teaching and learning mathematics – features such as the ability to display mathematical symbols or shared applications. The case study concludes with the recommendation and implementation of one of the Real Time Communication technologies.

In Chapter 8, the third case study describes the implementation of a special case of Real Time Communication Technologies, the Access Grid. This technology offers a dramatically different form of distance education. In the higher undergraduate levels, for honours and in postgraduate mathematics and statistics, there were often only small numbers of students. One of the associated problems was that the number of students who wanted to study these subjects was small and class sizes of one or two were not adequate to efficiently run the subjects. The Access Grid node installed at the University of Wollongong (UOW) with assistance from the International Centre of Excellence for Education in Mathematics (ICE-EM) allowed the sharing of subjects across universities with similar facilities.

The University of Wollongong was one of the lead universities involved in developing an Access Grid node. The evaluation in Chapter 8 documents the design, development, implementation and institutionalisation of a node on an Access Grid network connecting several Australian mathematics departments. The evaluation involves two kinds of communication setups: one for large group-to-group communications, the Access Grid; and one that is suitable for interactions between smaller groups, the personal interface to the Access Grid (PIG). Student and staff interviews and survey data have been collected and used to characterise the teaching and learning experiences arising from use of both setups of the Access Grid.

The final chapter summarises the outcomes of the case studies and contains a series of conclusions and recommendations.

Chapter 2

Review of the Literature

First, "knowing" mathematics is "doing" mathematics. A person gathers, discovers, or creates knowledge in the course of some activity having a purpose (National Council of Teachers of Mathematics 1989, p. 7).

2.1 Introduction

This thesis describes the use of technology in the improvement of mathematics education. One of the areas in mathematics where technology has been widely used is in the development of learning resources. Understanding the impact of technology-based learning resources in mathematics education requires an appreciation of:

- the issues in teaching and learning that are to be addressed by the use of technology and
- the outcomes of the use of technology in the context of outcomes from other initiatives and innovations.

The purpose of this literature review was to provide:

- the broad context for the development of mathematics learning resources for students undertaking tertiary studies,

- the means for situating the learning resources developed in terms of the issues associated with learning mathematics in a tertiary institution and
- the means for ascertaining the strengths and limitations of the learning resources developed.

In this chapter, the nature of the worldwide decline in mathematics is examined with particular focus on approaches to improving mathematical learning outcomes (Section 2.2). Before proceeding to examine approaches to improving learning outcomes, the nature of outcomes is explored. There are many different outcomes, including improved motivation, improved performance in tests and the demonstration of understanding, among others. The nature of approaches to improving outcomes is examined. These approaches include:

- programs to assist the transition into university life,
- programs to assist the transition into tertiary mathematics subjects, specifically Bridging Mathematics and Enabling Mathematics,
- changes to the curriculum,
- assessment strategies,
- learning support programs,
- non-technology based innovations,
- provision of learning resources,
- technology based innovations and
- a diverse range of other innovations.

2.2 Decline of Students' Mathematics Background

It is often stated that students entering university have less mathematics knowledge and a weaker mathematics background than students in previous years. Such trends have been identified worldwide, in Canada (Kajander & Lovric 2005), in France (Artigue 2001), in Hong Kong (Luk 2005), in Italy (Furinghetti 2000), in Japan (Hoyles, Newman & Noss 2001), in the United Kingdom (Howarth & Smith 1980; Kitchen 1999; Croft et al. 2000; James 2002; Mustoe 2002; Walkden & James 2003; Williamson et al. 2003) and in the United States of America (Cejda 1997; Wilson, W. S. 2007). A decline in mathematical ability has been identified for students entering a diverse range of disciplines including biological and social sciences (Wilson, W. S. 2007), engineering (Sutherland & Pozzi 1995; Gill 1999a, 1999b; Mavrikis & Macciocia 2002; Fadali et al. 2001a, 2001b; Williamson et al. 2003), mathematics (Luk 2005), physical sciences (Gill 1998) and science (Mavrikis & Macciocia 2002). These references suggest there is evidence of a decline in mathematics background which has existed for several decades.

In Australia, several recent reports have identified a decline in the percentage of year 12 students taking intermediate level and higher level mathematics (Ramsey 2000; Barrington & Brown 2005; Wolfe 2006). This decline is of major concern as it is thought it will have an adverse effect on 'the national capacity for innovation in engineering and technology' (Barrington 2006, p. iv).

The following areas have been identified as examples where student abilities, background and motivation have changed.

- Students have poorer *mathematical skills* than in previous years (Porkess 1994; Dearing 1996; Hunt & Lawson 1996; Armstrong & Croft 1999; Gill 1999a; Croft et al. 2000; Mavrikis & Macciocia 2002; Walkden & James 2003; Williamson et al. 2003).
- Students have poorer *conceptions of mathematics* (Nardi 1996; Furinghetti 2000; Ehmke, Haapasalo & Pesonen 2005).
- Students have poorer *analytical skills*, posing a serious obstacle for students completing simple questions that need more than one step (Howson 1995; Kahn & Hoyles 1997).
- Students have a poorer *ability to manipulate* algebraic expressions (Kahn & Hoyles 1997; Gill 1999a).
- Incoming students have less *interest* in mathematics (Gill 1999a; Furinghetti 2000; Kümmerer 2001).

Deficiencies have also been identified as a lack of:

- *technical talent* to do numerical and algebraic calculation (Howson 1995) and
- *feel* for the context of the subject or a lack of *deeper understanding* (Edwards & Edwards 2003).

Not only is there a decline in mathematical capabilities of students, but there are other changes which potentially compound the problems for academic staff. These include:

- *increasing proportion* of students entering higher education (Porkess 1994; Gill 1999a, 1999b; Taylor 2002; Wilson, W. S. 2007);
- *a widening syllabus* gap between school mathematics and university mathematics (Gill 1999a);
- the rapid pace of development in the use of *new technology* in teaching and learning (Taylor 2002);
- differences in *information communication technology (ICT) approaches* such as the different choices of packages used by mathematics at school and university (Gill 1999a);
- increasing *use of calculators* and associated loss of arithmetic skills (Hembree & Dessart 1992; Edwards & Edwards 2003; Wilson, W. S. 2007);
- increasingly *diverse academic* background of students (Shaw & Shaw 1997; Hargreaves 1998; Hoyles, Newman & Noss 2001; Mavrikis & Macciocia 2002; Teoh 2003; Williamson et al. 2003; Kajander & Lovric 2005; Alajääski 2006);
- increasing *cultural diversity* of students (Hargreaves 1998) and
- changes in the opportunity to practice mathematics skills rather than demonstrating an understanding of *fundamental concepts* (Gill 1998).

Other issues that may pose difficulties when teaching mathematics include:

- students *deferring mathematics subjects to later years* but meanwhile encountering the need for mathematics in their other subjects (Mavrikis & Macciocia 2002);
- *lack of lecture time* to reinforce basic mathematics skills (Mavrikis & Macciocia 2002);

- *lack of preparation of entering students* who are not equipped for the much higher level of *competition* and *intellectual sophistication* required by science, engineering, and mathematics disciplines (Hudspeth et al. 1998);
- the range of *abilities* and different *attitudes* towards mathematics (Shaw & Shaw 1997);
- *technology difficulties* encountered by some students in the transition from mathematics in high school to mathematics at university (Selden 2005) and
- negative experiences from *academic and personal problems* (Lowe & Cook 2003).

Multiple issues associated with low motivation and poor results were recognised by Teese (2002). These included the use of *teaching strategies* that do not engage the student in learning or that reduce student isolation, the *social* gap between high school and university education and *economic and cultural* difficulties.

The literature is dominated by suggestions that the gap between secondary and tertiary education in mathematics is increasing (Furinghetti 2000; Hoyles, Newman & Noss 2001; Luk 2005). An increasing gap is likely if the mathematical requirements in university courses are not being changed or lowered in response to changes in the pre-tertiary sector. There is also some mitigating evidence that suggests the mathematics requirements at university have, in fact, changed. The decline in ability in some mathematics topics might not be such a problem if tertiary level subjects are rewritten to reflect current needs. For example, Sutherland and Pozzi (1995) suggested that the topics of trigonometry, functions, calculus and graphs were less important for engineering mathematics in 1995 than they were in the previous decade. This is contrasted with the development of new engineering fields where the needs for mathematics may have increased (May & Chubin 2003).

In the United Kingdom, Croft et al. (2000) identified the need to restructure ‘the mathematical philosophy and content for engineering degrees’ (p. 77). The need to restructure the mathematics curriculum, in order to better enhance the ability of engineering students to incorporate mathematics into their professional subjects, has also been identified in an Australian context by Lopez (2007).

For engineering students, evidence of a decline in skills or poor skills has been found in several mathematical topics. For example, in Hong Kong, the United Kingdom, and the United States of America, these topics include algebra, arithmetic and calculus. Specific examples of mathematical topics in which there have been observed declines in skills include:

- algebra (Hunt & Lawson 1996; Howarth & Smith 1980; Gill 1998, 1999a; Armstrong & Croft 1999; Luk 2005);
- arithmetic (Hunt & Lawson 1996);
- calculus (Sutherland & Pozzi 1995; Hunt & Lawson 1996; Armstrong & Croft 1999; Wilson, W. S. 2007);
- Cartesian coordinates (Armstrong & Croft 1999);
- complex numbers (Gill 1998);
- differentiation (Armstrong & Croft 1999);
- factorisation (Howarth & Smith 1980; Gill 1998);
- functions (Sutherland & Pozzi 1995; Hunt & Lawson 1996; Armstrong & Croft 1999);
- graphs (Sutherland & Pozzi 1995; Hunt & Lawson 1996; Levine & Cureton 1998; Armstrong & Croft 1999);
- inequality (Howarth & Smith 1980; Armstrong & Croft 1999);
- integration (Armstrong & Croft 1999);
- logarithms (Gill 1998; Armstrong & Croft 1999);
- polar coordinates (Armstrong & Croft 1999);
- sigma notation (Armstrong & Croft 1999);
- rates of change and gradients (Armstrong & Croft 1999) and
- trigonometry (Sutherland & Pozzi 1995; Hunt & Lawson 1996; Gill 1998).

While most evidence points towards a decline in skills, this decline is not necessarily uniform across all topics. For example, Hunt and Lawson (1996) found that between 1991 and 1995 there was a significant difference in the ability of science and engineering students to answer questions in basic arithmetic, basic algebra, lines and curves, advanced algebra, trigonometry functions and calculus. There was no significant change in performance, however, on questions relating to the properties of triangles.

Not only is there a decline in the entry-level students' knowledge of mathematics, there is also evidence of deficiencies in the exit mathematical skills of engineers. Maddocks (2004) is emphatic about what is required of engineers:

> In engineering, knowledge is of little value in itself unless it can be applied to provide solutions for real world problems. As such, our engineering graduates need to be not only knowledgeable but skilled and competent in applying such knowledge. They need to be systematic in their approach, able to think critically, apply creative but practical solutions, and to reflect upon their practice (p. 183).

Others also suggest that there are problems with mathematics subjects not delivering appropriate graduate outcomes. For example, in the Australian context Trevelyan (in press) has identified several issues related to professional outcomes such as engineers who are reluctant to put their mathematical knowledge into practice. Trevelyan has suggested that although there does not appear to be any need for increasing the theoretical underpinning of advanced mathematics in engineering subjects, there is, in fact, a need to improve students' ability to transfer that mathematical knowledge to the engineering context in practice.

2.3 Students in Transition

The successful transition of students from high school mathematics into university mathematics, or subjects requiring mathematics, involves two aspects: those that relate to making the transition into any subject at university and those which relate specifically to the transition into mathematics. These transitions may be more difficult for one group of students than another. For example, the transition of students from minorities groups who are underrepresented at university may pose special problems (May & Chubin 2003).

The period of transition from high school to university may be as short as the first few weeks of session or as long as the first year of study. Innovations that help students make the transition successfully may lead to improvements in the performance of students not only in subjects studied in their first semester at university but throughout their degree. Furthermore, 'the gap may take many different forms, which vary with different education systems in different places at different times' (Luk 2005, p. 161).

2.3.1 Transition to University

For some students, there will be difficulties moving into studies of all disciplines including mathematics. For example, Hargreaves (1998) described factors for engineering entrants that have a negative impact on their transition to university. These included initial university tests; difficulties with learning and understanding in large classes; handling or prioritising large number of subjects and lecturers' expectations and

> … the impersonal feeling of a university, the 'little fish in a big pond' feeling, the feeling of not knowing any university staff, especially academics, and not knowing what is really expected of them, especially in terms of learning strategies and how their chosen field of study fits into the more global aspects of community (Hargreaves 1998, p. 79).

Wood (2001) described the difficulties in transition from secondary to university mathematics as a combination of 'mathematical content, … teaching and learning styles, and … personal and interpersonal adjustments' (p. 88). The rapid transfer from family and school to university may create anxiety and distress, undermining students' normal coping mechanisms with the consequent impact, under-achievement and dropping-out (Lowe & Cook 2003).

Many of these factors are not discipline specific. A variety of ways to assist students has been suggested. Wood (2001) identified approaches in many countries which smooth the transition. These included systemic solutions for senior or junior colleges, extended degree programmes, orientation, interaction with teachers in secondary schools, and school examinations. Shaw and Shaw (1999) suggested changes in the teaching methods for difficult mathematics topics, and teaching easier topics before difficult topics to improve students' confidence. May and Chubin (2003) found that the success of engineering students is associated with indicators such as 'pre-college preparation, recruitment programs, admissions policies, financial assistance, academic intervention programs, and graduate school preparation and admission' (p. 1). Hargreaves (1998) reported on three initiatives to assist engineering students in their development and adaptation to university learning, namely, an orientation program, a mentoring scheme, and a subject on technology and society. While this initiative, built into an ongoing program, was considered useful, some students 'felt that it was not useful and that time could be better spent doing 'real' engineering work' (p. 87).

Roberts and Higgins (1992) found that the transition into higher education is easier for students who had similar teaching and assessment at school. However, the type of learning that is required at university may be different to that at school. For example, students might be expected to be more independent in their learning. Teese (2002) suggested:

> … it is important to stress that tertiary transition is about entering a new phase of *learning*, not only about preparing for a career, and consequently that student orientations towards learning are (or should be) as relevant to how university places are filled as the quality of teaching in a university course … to choose their tertiary options not only on career lines, but on *pedagogical* grounds as well (pp. 17 & 18).

The development and examination of innovations to address the transition to university life fall outside the scope of this thesis. It is important to note, however, that successful completion of mathematics is also based upon a successful transition to university.

In the context of this thesis, the programs available to assist students taking part in this study are identified in Chapter 3.

2.3.2 Transition to University Mathematics

Hoyles, Newman and Noss (2001) suggested that the transition or 'gap' in mathematics is not new. The problems of transition were identified in the literature in the early 1970s:

> … the students do not understand the mathematical ideas which university teachers consider basic to their subject; they are not skilful in the manipulative processes of even elementary mathematics; they cannot grasp new ideas quickly or at all; they cannot write simple English clearly and grammatically; and, particularly, they have no sense of purpose - that is, they do not seem to realise that in order to study mathematics intensively they must work hard on their own trying to sort out ideas new and old, trying to solve test problems, and so on (Thwaites 1972, p. 5).

Tall (1992) described the difficulty as one proceeding from *concepts* to formal definitions and deductive knowledge.

> When students are first confronted with mathematical definitions it is almost inevitable that they will meet only a restricted range of possibilities that colours their concept images in a way that will cause future cognitive conflict … Cognitive roots are not easy to find-they require a combination of empirical research … and mathematical knowledge … A cognitive root is different from a mathematical foundation; whereas a mathematical foundation is an appropriate starting point for a logical development of the subject, a cognitive root is more appropriate for curriculum development (Tall 1992, p. 497).

De Guzman et al. (1998) suggested the transition to university mathematics required a major shift for students.

> [T]he mathematics is different not only because the topics are different, but more to the point because of an increased depth, both with respect to the technical abilities needed to manipulate the new objects and to the conceptual understanding underlying them (De Guzman et al. 1998, p. 752).

The transition from school to university level mathematics, however, remains an issue. Current literature examines different aspects of the transition from high school mathematics to tertiary mathematics. Transition may refer to the change:

- in proficiency required in *mathematical thinking* and *skills* at the school level to that required at the tertiary level (Hoyles, Newman & Noss 2001; Wood 2001; Johnson 2002; Robinson & Croft 2003; Britton et al. 2005; Haines & Crouch 2005; Kajander & Lovric 2005; Luk 2005; Selden 2005);
- from *experimental* mathematics to *abstract* mathematics (Nardi 1996);
- in the need for more difficult *proof* of theorems (Furinghetti, Olivero & Paola 2001);
- from *procedural* thinking to *abstract conceptual* thinking (Ehmke, Haapasalo & Pesonen 2005) and
- from *slow* to *faster pace of mathematics* and to differences in the assessment and examination system (Luk 2005).

'Bridging' and 'enabling' mathematics subjects provide students with an opportunity to fill the gaps of transition from mathematics at high school to mathematics at university.

2.3.2.1 The Use of Bridging and Enabling Mathematics Subjects

Bridging subjects may be used to fill gaps in mathematics knowledge and skills in incoming students, to develop the precise attitude and language of mathematics and to develop computing skills where appropriate (Wood 2001). Bridging subjects provide an opportunity for both recent school leavers and mature-age students to 'catch-up' (Milne 1992) or in an alternative framework to develop their mathematical learning Taylor (2002). Taylor suggests the majority of bridging mathematics programs are designed 'based on a developmental model of learning rather than a deficit model' (p. 68).

There is no clear distinction between the content of bridging and enabling subjects. Programs to bridge the gap may vary in timing, (either before or after university entrance) and duration. They may also vary in that they may, or may not, be counted as part of students' work load. At the University of Wollongong, Bridging Mathematics was a short subject, typically lasting two or three weeks, that was taken immediately prior to entering university. Enabling Mathematics, instead, was a longer program of 13 weeks, taken over the first session of study, which allowed students to enrol in an engineering degree while they developed the necessary skills to complete the required mathematics subject. Boland (2002), at the University of South Australia, referred to a 'mathematics bridging' subject as a one semester full-time or two semester part-time subject prior to university entry. The use of the term 'enabling' subject has acquired an additional connotation with the Australian Commonwealth Government providing funding for 'enabling' subjects.

Bridging subjects may vary in the type of learning environment created. For example, Baker, Crampin and Nuttall (1973) found that students could increase mathematics knowledge more by solving mathematics problems dynamically than by inactively digesting lecture notes. They ran a 'Crash Course' with the aim of developing technical facilities that consisted of a programmed text, films and demonstrations of numerical techniques for engineering and chemistry students. It was a successful course in terms of pre-test and post-test results, in student enjoyment of the course and in teaching skills to students in calculus.

Bridging subjects also vary in the use of assessment to deliver outcomes. Howarth and Smith (1980) provided a bridging subject running in parallel with undergraduate subjects during the first semester. Based on pre-test and post-test results they found a significant improvement in manipulative abilities in numerical and algebraic work for engineering students. The subject was based on the Keller (1974) plan, where students were given additional materials to work through until they could get all questions correct in their test. Students worked through units independently, at their own pace, and then attended a one-hour tutorial per week to discuss any difficulties.

Bridging subjects may also vary as to the degree to which students are required to undertake independent learning. Taylor (2002), for example, discussed three models for the provision of online mathematics courses at the University of Southern Queensland. These models are the *independent learner* or lone learner; the *interactive learner*, typified by teacher and learner interactions; and the *collaborative learner* or many-to-many experience. One of the difficulties with the independent learner model is that it focuses on the provision of resources and the individual student must take the initiative to participate. The most successful aspect of the online initiative has been the 'Self Test Package, suite of mathematical topics in downloadable form, a series of online synchronous tutorials and access to one-to-one support via email or phone' (Taylor 2002, p. 70). The precise nature of the success is unclear, however the project has been extended to disciplines other than engineering.

Other approaches include the development of integrated curriculum in which students observe the links between disciplines. For example, Hudspeth et al. (1998) developed an integrated mathematics, physics and engineering subject. The authors indicated that one of the benefits of the program was that it acted as a forum for cross-disciplinary interchange which led to 'a deeper understanding of the problems students typically experience when presented with mathematics, physics, and engineering mechanics in a sequential format' (p. 1044).

Outcomes from Bridging subjects include better motivation (Wood 2001), positive attitudes (Wood 2001), improved mathematical skills (Boland 2002) and a higher proportion of students who successfully progress through their degrees (Boland 2002). Other outcomes for bridging subjects include an increase in grades, improvement in students' performance, improved self-confidence and the ability to manage multiple demands (Hudspeth et al. 1998).

2.4 Learning Outcomes

Before examining the innovations that have been made in order to improve the teaching and learning of mathematics, it is appropriate to identify the specific nature of possible outcomes.

There are several different taxonomies of learning that define types of learning and which can be used as a basis for defining the desired outcomes of the teaching and learning of mathematics. For example, Bloom et al. (1956) presented six levels of educational objectives – knowledge, comprehension, application, analysis, synthesis and evaluation – which reflect increasing levels of learning. In order to measure these, the tasks or questions that are posed by assessment may require different levels of responses. Examination of changes that countries are making in terms of curriculum (Section 2.6.1) also reveals an attempt to change the nature of the learning in which students are engaged in order to reflect what such taxonomies are saying about the nature of learning. Similarly, an examination of research on assessment (Section 2.6.2) reveals that a number of researchers have attempted to manipulate the type of learning that a student engages in, whether it be in terms of Bloom's taxonomy or one of a number of other taxonomies.

Freeman and Lewis (1998) suggested that Bloom's taxonomy is not very helpful in assessing problem solving, 'except for simple problems where the learner applies an identified method' (p. 238). Freeman and Lewis provided alternative levels to Bloom's taxonomy, suggesting: routines, diagnosis, strategy, interpretation and generation. Other taxonomies can also be used to examine the nature of learning. For example, the Structure of Observed Learning Outcomes (SOLO) developed by Biggs and Collis (1982) categorised learning as having: 'Extended Abstract, Relational, Multistructural, Unistructural, and Prestructural' levels (pp. 24-25). Groth (2004) defined these terms as:

> Prestructural responses show little evidence of learning relevant to the task at hand. Unistructural responses focus upon just one relevant aspect involved in completing a task. Multistructural responses incorporate more than one relevant aspect, but there is no unifying theme for the aspects. At the relational level, a unifying theme is apparent along with multiple relevant aspects. Responses at the extended abstract level are "breakthrough" responses that are not just coherent applications of academic learning, but go beyond the task at hand to apply the coherent whole to new areas (http://www.allacademic.com/meta/p117522_index.html).

Hattie and Brown (2004) further classified the SOLO taxonomy into two stages: 'surface and deep (Surface = Unistructural and Multistructural; Deep = Relational and Extended Abstract)' (p. 5). This has been further extended with researchers describing approaches to learning; in terms of a *Deep* approach, a *Surface* approach and a *Strategic* approach (Entwistle 1987). Having students adopt one or other approach is often a desired outcome. Crawford et al. (1998) found that those incoming students who adopted a surface learning approach to mathematics were less successful than those who learnt with meaning and understanding (deep approach). Hattie and Brown (2004) noted that:

> … it is critical to note that both surface and deep cognitive processes are needed when mastering school work; it is not the case that Surface is Bad, Deep is Good. It is a cliché, but it is difficult to be deep without some surface material to think deeply about. Students must be able to master both surface and deep thinking … (p. 26).

One criticism of mathematical learning at university is that sometimes there is too great an emphasis on surface learning. For example, 'The power of mathematics as a tool ... is that if the working of the tool is understood then it becomes possible to apply it in novel situations' (Gill 1999a, p. 87). Gill (1998, 1999a, 1999b) found the learning of mathematics to be the learning of a set of disconnected skills in order to pass tests. When the *context* or style of the problem was transformed, students failed. There is, for example, a need for engineering students to transfer the application of mathematics knowledge, skills and attitudes learnt in their mathematical subjects to their engineering subjects. In discussing the transfer of mathematics, Lampert (1990) wrote:

> … a vision of knowing mathematics in the discipline that differs from knowing mathematics in conventional classrooms. My research examined whether it was possible to make knowing mathematics in the classroom more like knowing mathematics in the discipline (p. 59).

Lampert indicated that by engaging students in mathematics discourse they could carry some expectations about how one does mathematics in the mathematics classroom into other disciplines.

Another attribute or outcome that is often sought in higher education is that of independent learning because, while it can simply refer to student-initiated mastery of knowledge, in the strongest meaning of the term, it facilitates the higher levels of Bloom's and other's taxonomies of learning. For example, the University of Wollongong identifies first in its list of desirable graduate attributes:

> A commitment to continued and independent learning, intellectual development, critical analysis and creativity (http://www.uow.edu.au/about/teaching/graduate_attributes.html).

Although independent learning was defined by Moore (1984) as '… deliberate and planned adult learning that did *not* rely on professional teachers, courses, classes, or even educational institutions' (p. 15), a definition which could potentially limit itself to simple knowledge or comprehension, Kesten (1987), instead, explained independent learning as 'autonomous learning, independent study, self-directed learning, student-initiated learning, project orientation, discovery and inquiry, teaching for thinking, learning to learn, self instruction and life long learning' (p. 2). Chan (2001) cautioned 'if the learner does not understand the reasons and benefits of autonomous learning, he/she may refuse the extra responsibility for and involvement in the learning process' (p. 515). Independent learning as an approach to the lifelong process of student learning can be more meaningful when it is:

> … based on their understanding of why and how new knowledge is related to their own experiences, interests and needs … Independent Learning can assist students in acquiring the knowledge, abilities, skills, values and motivation that enable them to analyze learning situation and develop appropriate strategies for action (Saskatchewan Education 1988, http://www.sasked.gov.sk.ca/docs/policy/cels/el7.html#e12e12).

Broad (2006) referred to the aims of independent learning as teaching 'students to learn for themselves and in turn empower them in their learning whatever the context' (p.

121). Souto and Turner (2000) recognised that some confusion existed with the meaning of the terms *independent study*, *autonomous learning*, and *self-access systems*:

> … they may still mean different things to different people in different institutions employing different practices, generally speaking these terms are nevertheless interrelated and refer to, on the one hand, a trend towards encouraging more independent modes of study on the part of the learner (learner autonomy) and on the other hand, the provision of materials and resources which are aimed at facilitating this independence (self-access centres) (p. 385).

Race (1996) assumed that the choosing and obtaining of resources is a key indicator of independent learning, when he argued that most learning could be viewed as both independent learning and as resource-based learning as long as the traditional list of resources used by students is expanded to include human resources, such as tutor and mentors, and information-type resources, such as books, online databanks and lecture notes. He suggested that students using learning resources at their own pace are in fact learning independently. However, it could be argued that if the learning resources have been structured to lead students to a particular learning experience then students have not learned to seek, identify and develop the structure for themselves and, in this sense, the learning resources are not truly demonstrations of independent or autonomous learning.

Other outcomes sought in Mathematics Education include conceptual understanding, procedural fluency and problem solving. The New York State Education Department (2005) defined these as:

> Conceptual understanding consists of those relationships constructed internally and connected to already existing ideas. It involves the understanding of mathematical ideas and procedures and includes the knowledge of basic arithmetic facts. Students use conceptual understanding of mathematics when they identify and apply principles, know and apply facts and definitions, and compare and contrast related concepts … Procedural fluency is the skill in carrying out procedures flexibly, accurately, efficiently, and appropriately. It includes, but is not limited to, algorithms (the step-by-step routines needed to perform arithmetic operations) … Problem solving is the ability to formulate, represent, and solve mathematical problems. Problems generally fall into three types: one-step problems, multi-step problems, process problems (p. 3).

Hollands (1972) defined the outcomes, *creativity*, *divergent thinking* and *production* in mathematics as involving:

> … fluency, shown by the production of many ideas in a short time; flexibility, shown by the student varying the approach or suggesting a variety of methods; originality, which is the student trying novel or unusual approaches; elaboration, shown by the extending or improving of methods; and sensitivity, shown by the student criticizing standard methods constructively (cited in Imai 2000, pp. 187-188).

There is a variety of outcomes that can be examined such as those already identified and often those commented upon when researchers have found their attainment problematic. These include:

- the ability to transfer learning from one area to another or from mathematics to a particular discipline (Nunes & Bryant 1996; Porkess 2003);
- retention rates (Edwards & Edwards 2003);
- reduction of mathematical misconceptions (Edwards & Edwards 2003);
- increasing motivation and interest (Milne 1992; Beevers & Paterson 2003) and
- students' *confidence* in using mathematics (Eccles & Jacobs 1986; Rowe 1988).

Just as there is a variety of outcomes, there are a variety of educational approaches that can be applied to obtain these outcomes. These approaches are discussed in the next section.

2.5 Theoretical Approaches to Teaching and Learning

Philosophies of education, or theoretical approaches to teaching and learning, are the broad belief systems that stand behind the decisions of curriculum designers. Some refer to these as 'Schools' (Baruque & Melo 2004), probably referring to schools of thought. These philosophies, theoretical approaches, or schools should not be confused with methods. Methods are practical approaches that academic staff use in order to achieve the learning objectives. Philosophies guide the design, selection, and implementation of methods. When reviewing the literature, innovations are often couched in terms of the philosophical approaches driving their introduction. Curriculum redesigns often reveal their philosophical roots (Section 2.6.1).

Ramsden (2003) suggested that university teachers have concepts of teaching and learning that are reflections of their own philosophies. He referred to these as ‘Theories’ and stated that they have three categories: *teaching as telling or transmission, teaching as organising student activity* and *teaching as making learning possible*. Ramsden argued that the theory adopted by a university teacher will affect the teacher’s focus, strategies and activities used and guide their reflection on improving teaching and learning.

Baruque and Melo (2004) appear to concur with Ramsden and argued that the three ‘major learning schools’ were behaviourism, cognitivism, and constructivism. They described behaviourism as based on how the external environment shapes students’ behaviour, which is similar to Ramsden’s ‘theory’ of teaching as organising student activity. Behaviourism was a popular approach to learning in the middle of last century. Seemingly, Tyler (1949) believed it was the only way students learned.

> Learning takes place through the active behavior of the student; it is what *he* does that he learns, not what the teacher does (Tyler 1949, p. 63).

Baruque and Melo (2004) described cognitivism as based on changes in students’ memories. This approach appears difficult to map to one of Ramsden’s theories of teaching. While it appears closest to ‘teaching as telling or transmission’, cognitivism goes further than simply providing information. Ramsden, in fact, suggested that the outcomes of learning should not be limited to memories, just as Bruner (1966) argued that acquiring knowledge should not be the sole outcome of teaching and learning.

> We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as an historian does, to take part in the process of knowledge-getting. Knowing is a process, not a product (Bruner 1966, p. 72).

While Ramsden’s third theory at first appears somewhat general, it implies a learner-centred approach that is a salient element of constructivism. Ramsden did not refer to constructivism by name, but significant similarities can be drawn between *teaching as making learning possible* and constructivism. Ramsden (2003) and Baruque and Melo (2004) argued the importance of learner centeredness and creating a context in which students engage with the subject material. They imply an epistemology that assumes students construct their own knowledge. Baruque and Melo (2004) described constructivism as learning that is constructed by a 'complex interaction among students' existing knowledge' (p. 346). Jacobs (2005a) took a less social approach to the definition of constructivism, describing constructivism as emphasising that students take control of their own learning. They are active and are '… encouraged to explore, investigate and question any new concept, presented to them' (Jacobs 2005a, p. 763).

Jacobs suggested that online learning can have a constructivist approach by providing ample opportunities for students to interact with, and take control of online resources.

> The ability to choose navigational sequences, interact with solutions, modify parameters and create graphs or examples of an approach that encourage student-centred learning (Jacobs 2005a, p. 763).

Constructivism is based on the premise that knowledge is subjective not objective. In many studies it is the preferred theoretical approach to teaching and learning, with articles identifying teaching methods or curricula that focus on ways to facilitate students building knowledge. For this thesis, constructivism is defined as an approach to, and underlying philosophy of, learning in which students are allowed to construct their own knowledge through connecting their own experiences and thoughts with the learning environment. Constructivism is about learners building personal knowledge rather than absorbing 'facts'. In the literature, constructivism is often contrasted to instructivism, which is an underlying philosophy of education that is characterised by the delivery or transmission of knowledge from the teacher to the students. Instructivism is an approach that is sometimes seen as making mathematics difficult for students to understand (Crawford et al. 1998).

The literature often argues that constructivism is the most appropriate philosophy of teaching and learning, but perhaps this may not be true in every context. Perhaps there are constraints of budget or time, cultural differences, or other issues which might suggest constructivism is not the best approach for all teaching and learning. As Baruque and Melo (2004) wrote:

> Disappointingly, some radical researchers assume that constructivism can be applied to every educational situation, disregarding its context and ignoring the historical success and the contributions that the previous schools have made to learning in the last century (p. 367).

In fact, pedagogies to address gaps in the mathematics education of incoming university students or simply to develop mathematical knowledge have been based on all three approaches. Some derive from an instructivist approach. They concentrate on the transfer of information or skills to students. Other techniques are based on a constructivist approach (Jacobs 2005a) where the emphasis is on students constructing mathematical knowledge.

Other commentators on theoretical approaches to teaching and learning mathematics describe the shortcomings of instructivism in teaching and learning mathematics. Crawford et al. (1998) drew on suggestions by Scardemalia and Bereiter (1994) that mathematics is taught to students at school and university as a completed and polished subject and Dreyfus (1991a) stated that students are taught mathematical skills but the processes by which the concepts and worked solutions have been developed are unknown to them.

Many commentators (Boland 2002, Jacobs 2005a) suggest that constructivism is the most appropriate theoretical approach for the teaching and learning of mathematics. However, Baruque and Melo (2004) disagreed and argued that the long history of teaching and learning mathematics should not be ignored. The classical model of teaching mathematics is characterised by the sequence ‘lecture-examples-exercises’ (Borba & Villarreal 2005). Indeed traditional methods such as lectures and presentations have been identified as excellent ways of transmitting new information (Bransford, Brown & Cocking 2000). Chapter 4 of this thesis reports on a suite of video resources that were developed to assist students in developing basic mathematical skills. In this thesis, the resources represent the ‘exercise’ component of the classical model where the primary mode of instruction was delivered by lecturers. The video solutions instruct students on how to complete the solution rather than, for example, experiencing mathematics through ‘what-if’ type animations. The resources were student-centred, however, in that they met student needs for access to additional instruction on specific topics with which they were having difficulty. They also allowed students to use them at a time of their choosing.

The debate between differing philosophies or theoretical approaches will continue beyond this thesis. What is evident is that several philosophical schools of thought underpin many of the innovations that have been implemented in the classroom and in curriculum change.

2.6 Approaches to Improving Learning Outcomes

The initial literature review focused on identifying major approaches to smoothing the transition into university studies. The literature review then identified several major approaches to improving mathematics outcomes. This section is structured according to the approaches used to bring about change as follows:

- Changes to the Curriculum (2.6.1);
- Using Assessment to Facilitate Different Forms of Learning (2.6.2);
- Mathematics Learning Support (2.6.3);
- Non-Technology Based Innovations (2.6.4);
- Provision of Learning Resources (2.6.5) and
- Technology Based Innovations (2.6.6).

2.6.1 Changes to the Curriculum

Curriculum change has been suggested as a solution to a number of problems. One of these is the tension between requiring students to master skills and requiring them to understand how and where those skills can be used in solving real world problems. For example, engineers need to be able to apply mathematics to solve problems such as how to best build bridges or materials; it is of little use if the mathematical skills cannot be used when they are required to solve a problem. It often appears that these two objectives are in opposition, that there is time for one but not the other. This is illustrated by Engelbrecht, Harding and Potgieter (2005). The reform calculus program at the University of Pretoria in South Africa sought to combine both skill and conceptual development, and in fact, they found that an improvement in the students' conceptual understanding did not come with a loss to their proficiency in mathematical skills. The reform approach to teaching calculus provided an emphasis on understanding problems, with concepts being introduced in four ways: 'verbally, numerically, algebraically and visually' (p. 710). The reform approach was described as:

> … rather than drilling students in the differentiation process, a premium is placed on the meaning of a derivative, what it tells you and how it can be used (pp. 710-711).

Calls for curriculum change are not restricted to requiring students to understand how skills can be used to solve real world problems. For example, Thompson (1992) suggested

> … the need to revise curricula to include courses in the history and philosophy of mathematics … It appears that much about the nature of the discipline is effectively conveyed by the very manner in which instruction in the content of mathematics is conducted (p. 141).

Curriculum change may also need to be driven by changes in technology. For instance, Viskic, Cooks and Petocz (2006) showed that students with a reasonable combination of mathematical insight and proficiency in the use of mathematics could score highly on a secondary school matriculation exam, a tertiary preparation course and a first year university service course in mathematics. They argued that students should be allowed access to an approved computer algebra package to handle 'routine calculations' in examinations. By freeing students from the need to 'crank-the-handle' on routine calculations, examinations could focus on conceptual problems.

After an extensive journal and web search for articles, two complete sets of conference papers were reviewed to examine if any current themes in the literature had been overlooked. These were the papers presented at *MERGA 28-2005* (Mathematics Education Research Group of Australasia) conference and *EARCOME4 2007* (Fourth East Asia Regional Conference on Mathematics Education). Analysis of these conference proceedings revealed that many countries have engaged in a process of curriculum reform, ranging from kindergarten through to year 12, to improve the outcomes of the teaching of mathematics. Authors, speaking in relation to their countries, described a need for change from a traditional approach, which is often viewed as having an emphasis on content, rote learning, memorising, to the reform curriculum. Examples of curriculum change or need for change come from the countries such as China, New Zealand, USA, Singapore and Australia.

2.6.1.1 International Changes to Curriculum

In China, changes were discussed in the context of developing and trialling textbooks as part of the design of the Mathematics Curriculum Standard (MCS). The reform curriculum suggested that content should connect to real life, engage students in investigation and cooperation, build students' self-awareness and self-confidence. The mathematics classrooms need to be transformed from totally teacher-centred to moderately student-centred (Xiaotian 2007).

In a discussion of curriculum and Confucian Heritage Culture (CHC), Wong (2007) suggested the East and the West should come together to explore 'the "**middle zone**" so that we can get the best of the two worlds' (p. 26). The middle zone relates to dichotomies of 'old or new, skills or concepts, concrete or abstract, intuitive or formal, inductive or deductive' (Hill 1976, p. 442), and a balance between content and processes. Wong suggested that we need to 'construct a bridge from "basic skills" to development of various process abilities, instead of just striking a balance' (p. 29).

The New Zealand Numeracy Professional Development Projects discussed the curriculum in the context of intermediate schools, years 7-10. The aims for this project were to develop students' number sense, to improve their knowledge, ability to respond to numerical questions and mental operational strategies (Britt & Irwin 2005). The Numeracy Project also involved the improvement of the professional knowledge of teachers so as to improve students' learning in mathematics (Young-Loveridge 2005). Professional development as inspired by the Numeracy Project includes developing professional skills such as learning to notice, reforming content knowledge, constructing, enacting and negotiating knowledge within a class, choosing appropriate ways to present subject matter and ask questions, skills to develop discussion and an ability listen to students' ideas (Davies & Walker 2005).

In Singapore, Yoong (2007) discussed developing a Pentagon framework for the mathematics curriculum with problem solving as a central focus along with other factors: *concepts*, *skills*, *processes*, *attitudes* and *metacognition*. The aims included developing mathematical ability to solve problems ranging from simple exercises to complicated open-ended questions. Thirty per cent of curriculum time was to be used to integrate ICT in the classroom to support the aims of the program including the integration of graphics calculators in mathematics.

The National Council of Teachers of Mathematics' (1989) standards in the USA suggested that oral and written communication in mathematics class should be used by teachers to give students opportunities to think through problems, to formulate explanations, to develop conceptual understanding and to reflect on their understanding. The reform pedagogy involved the use of student knowledge to inform instruction, encouraging classroom discourse, student autonomy, and increasing use of technology (Dindyal 2005).

A prominent trend in these papers is an emphasis on including technology in the contemporary mathematics curriculum. Yang (2007) highlighted the use of technology through the following examples:

- replacement of complicated algebra by calculators or computers in Taiwan,
- use of graphics calculators by A-level students from 2006 and for Grade 5-6 in 2007 in Singapore,
- use of an approved graphics calculator by students for the Victorian Certificate of Education (VCE) mathematics examinations from 2000 in Australia,
- use of MathLabs in 7000 high schools in India,
- workshops on graphics calculators for teachers in Malaysia,
- use of technology in mathematics to increase confidence in arithmetic computations in the USA and
- use of technological tools for oral examinations from 2004 in France.

2.6.1.2 Australian Changes to Curriculum

There have been curriculum changes in several Australian states. For example, Spyker (2003) discussed changes in Western Australia. In New South Wales (NSW), where most of the students in this study have completed their schooling, there is currently a curriculum review of years 11 and 12 mathematics. In addition to specifying topics, there is emphasis on how deeper learning may be better engendered than is possible by a skills approach. The current curriculum specifies the highest level of student outcomes for the student as follows:

- Exhibits extensive knowledge and skills appropriate to the Mathematics course
- Uses sophisticated multi-step reasoning
- Integrates ideas of calculus with strong algebraic, deductive and modelling skills to successfully solve difficult problems
- Exhibits excellent problem solving skills
- Communicates effectively using appropriate mathematical language, notation, diagrams and graphs (*Draft Performance Bands Mathematics,* http://www.boardofstudies.nsw.edu.au/syllabus_hsc/syllabus2000_listm.html#macedonianc).

Stillman (2001) identified a need for the Australian curriculum to move from the traditional focus on content to a reform approach:

> The impact of a school based assessment system on the implementation of an application/modelling based curriculum at the senior secondary examined … move from a curriculum focused on knowledge of content to an emphasis on mathematical modelling and applying mathematics to real-life situations – in solving both closed and open problems … the Board have endeavoured to encourage schools to move forward with new approaches to teaching and assessing mathematics, in particular, alternative assessment. The Board relies on, and believes in, the professionalism of teachers to take up the challenges of these new approaches (pp. 101 & 106).

In its *Statement on the Use of Calculators and Computers for Mathematics in Australian Schools* the Australian Association of Mathematics Teachers Inc. (1996) wrote:

> The influence of technology emphasises the importance of some aspects of curriculum content (such as discrete mathematics and chaos theory) and process (such as estimating, approximating, evaluating results), while diminishing the role of others (such as repetitive algorithms and rote learning). It implies a fundamental shift in educational priority, from

> accumulating knowledge to the management of information, and suggests an increasing need for citizens who are informed, critical and capable as decision-makers in a technological world (p. 5).

In NSW, there is specific instruction in the 1997 policy document *Computer-Based Technologies in the Mathematics Key Learning Areas* that technology be integrated into all disciplines for school years K-12. In the tertiary sector there is also some recognition of the need to teach mathematics in a technological context. In Australia as overseas, there are papers on the advantages of integrating the use of Computer Algebra Systems (CAS) packages into school teaching. For example, Ball and Stacey (2005) found that students used CAS reflectively, to get answers quickly and to check answers. Subjects are now being designed around the use of CAS, for example, the Mathematical Methods (CAS) unit as an alternative to the Mathematic Methods Units 1-4 in Victorian schools (Evans, Norton & Leigh-Lancaster 2005).

In a literature review examining ways to adapt mathematics education to meet the need of 21st century engineering students, Lopez (2007) identified several strategies. These included ways to improve teaching, learning and the mathematics curriculum for engineering students. Lopez recommended: the use of advanced computer based methods – web based interactive or software applications, or both; the use of a multidisciplinary approach; the use of the Problem Based Learning (PBL) strategy and that the issue of student differences in mathematical background, life circumstances and learning style be addressed.

In conjunction with changing the curriculum, there is an associated need to prepare teachers to implement the changes. In the Northern Territory of Australia, Jacob and Frid (1997) drew attention to the importance of providing professional development in relation to curriculum change in mathematics:

> … whatever strategies teachers might have learned during pre-service training, or even in subsequent in-service activities, changing approaches to teaching and curriculum change bring with them a need for teachers to develop new techniques (p. 5).

This focus on how to develop teachers professionally is extended in Section 2.6.4.1.

Other authors such as Tobias are critical of reform approaches that focus on curriculum and pedagogy without equivalent attention being paid to grading practices (http://www.sheilatobias.com/talks.html).

2.6.2 Using Assessment to Facilitate Different Forms of Learning

> … curriculum and teaching reforms over the past four decades in many countries has shown that the intended reforms most often founder on failure to match assessment techniques with the intentions of the reforms. Curriculum designed on the finest principles with the very best intentions makes no change to what goes on in the classroom if assessment produces remain the same. It is apparent that the practitioners, who are now at the forefront of curriculum change, are insisting that any reforms must be ‘assessment-led’ (Collis 1992, p. 36).

Many authors have noted that the way in which assessment is conducted is associated with whether or not students engage in surface or deep learning (Smith & Wood 2000; MacFarlane, Markwell & Date-Huxtable 2005). For example, the alignment of objectives, marking criteria and assessment questions has been used to shift student learning from lower order thinking skills such as calculation and rote learning, to higher order skills such as interpreting (Morris, Porter & Griffiths 2005). This alignment is important:

> The evaluative process must not be dissociated from the style of teaching. So, if we try to teach through problem-solving of real-life situations, in context with other subjects, assessment must be carried out in the same way. This purpose can be put into practice through project-work, where students (with orientation of an interdisciplinary team of teachers) try to solve real problems of their careers, in order to approve their mathematical courses (Martinez Luaces & Guineo Cobs 2002, p. 7).

One failure in learning outcomes that is often discussed is the inability to transfer learning to other contexts. This inability to transfer suggests that learning has taken place at a shallow level. Investigating different approaches to asking mathematics questions either with or without discipline context (Figure 2.1), Britton (2002) found that Australian science and engineering students may do well in mathematics, but may be unable to apply the content in the context of the scientific discipline.

Please see print copy for figure 2.1

Figure 2.1 Examples from Britton (2002)

Smith and Wood (2000) identified the need to teach and assess in context.

> Changing teaching without due attention to assessment is not sufficient … The rationale is that the mathematics should be introduced in context and the assessment reflects this (Smith and Wood 2000, p. 125 & 130).

Even within a mathematical approach to formulating questions students may demonstrate surface learning. Davis and McGowen (2005) created pairs of questions to access students' knowledge of linear equations and inequalities (Figure 2.2). When questions were posed on the same topic in different ways, they found that students' answers were often incorrect for one of the pair and that:

> ... students are unable to apply what they do know when confronted with a different context … what little they have learned and remembered is fragmented and unconnected and leads one to believe that their knowledge of slope and linear equations is quite fragile (p. 22).

Please see print copy for figure 2.2

Figure 2.2 Examples from Davis and McGowen (2005)

While 'multiple-choice tests can yield a large amount of information regarding students' abilities to perform simple skills in isolation, or their knowledge of discrete facts'

(Grouws & Meier 1992, p. 92) there is considerable criticism of the domination of multiple-choice tests as a form of assessment. For example, the National Research Council (1989) decries the impact that they have on students.

> … multiple-choice tests as used in America lead to widespread abuses, which the public rarely recognises:
>
> - Tests become ends in themselves, not means to assess educational objectives. Knowing this, teachers often teach to the tests, not to the curriculum or to the children.
> - Tests stress lower-[order] rather than higher-order thinking, emphasizing student responses to test items rather than original thinking and expression.
> - Test scores are sensitive to special coaching, which aggravates existing inequities in opportunities to learn.
> - Tests reinforce in students, teachers, and the public the narrow image of mathematics as a subject with unique correct answers.
> - Timed tests stressing speed inhibit learning for many students.
> - Normed tests ignore the vast differences in rates at which children learn.
> - Tests provide snapshots of performance under the most stressful environment for students rather than continuous information about performance in a supportive atmosphere.
> - Poor test scores lead students to poor self-images, destroying rather than building confidence (National Research Council 1989, pp. 68-69).

Along with the recognition that narrow forms of assessment '… tend to stress simple skills, rather than higher order thinking' (Grouws & Meier 1992, p. 90), researchers have begun to experiment with different forms of assessment in an effort to make learning more appropriate for living and working for today's society. Examples of these innovative approaches to assessing students include: the use of a mock 'conference day' to engage students in writing and presenting research papers to improve mathematical communication, critical thinking, reflection, mathematical modelling skills, free thinking, and creativity in interpreting problems (Mallet 2007); the engagement of students in the construction of multiple-choice questions thus developing learner self-regulation, and providing prompt feedback to students through peer commentary (Nicol 2007). These types of assessment strategies fit with known approaches such as projects, experiments, collaborative tasks and poster creation that attempt not only to develop mathematical skills but to attain a wider range of outcomes.

There is increasing recognition of the limitation of some forms of assessment and the need for alternatives to measure cognitive learning outcomes. For example, Lian and Idris (2007) have sought to assess students' level of linear equation solving using the SOLO taxonomy and partial credit for work. Similarly, Kamol (2007) formulated a framework to characterise students' thinking on patterns based on the Structure of Observed Learning Outcomes (SOLO) Model.

2.6.3 Mathematics Learning Support

Wilson, T. (2007) found that twenty-eight Australian universities provide some form of mathematics learning support including drop-in sessions, workshops, enabling subjects, resources and bridging subjects. Eleven Australian universities were listed as having no significant mathematics learning support. While most forms of learning support focus on 100 level students, a proportion of these offer support for postgraduates in statistics.

Another form of mathematics learning support adopted by universities worldwide is the *Peer Assisted Study Sessions* (PASS) program or variants such as the *UTS Peer Assisted Study Success* (U: PASS) or *Peer-Assisted Study Scheme* (PASS). PASS runs in several Australia universities including the University of Queensland, the University of Technology Sydney, the University of Melbourne, and the University of Wollongong.

> [PASS] Groups are informal, flexible and responsive to students' abilities and needs. In a typical session, students may compare notes, work through problems and past exam questions, share study tips and discuss course material with each other and their Peer Leader. Not only is it an effective way to learn, the U:PASS program is a great way to network with fellow students, especially if you don't have much time to hang out on campus.
>
> The U:PASS program employs cooperative learning methods, which encourage the use of small groups of students who collaborate in order to improve their own learning skills as well as the skills of others. These methods are based on various theoretical perspectives including behavioural learning theory, social interdependence theory and cognitive-developmental theory (http://www.ssu.uts.edu.au/peerlearning/).

Hirst, Williamson and Bishop (2004) referred to *Peer-assisted learning* as an approach to mathematics support with the aim of giving a supplementary level of academic support to students and providing the opportunity for students to learn form their peers.

> Schemes where students help each other to learn are becoming increasingly attractive to university departments throughout the disciplines. This method of support offers a very cost-effective way to implement various pedagogical aims and to train students in useful transferable skills (Hirst, Williamson & Bishop 2004, p. 114)

Other learning centres involve a mix of pre-sessional courses complemented by within-session support. Armstrong and Croft (1999) used a student confidence survey in basic mathematics skills and a diagnostic test to find out which topics needed more learning support. Their innovation referred to a pre-sessional course and the provision of extra learning resources utilising a range of media provided by the Mathematical Learning Support Centre.

2.6.4 Non-Technology Based Innovations

When speaking of innovations to improve some aspect of learning, researchers may describe the impact of a single innovation – for example, the introduction of a computer algebra system, or they may speak in terms multiple aspects of a subject being associated with a particular outcome or outcomes. Changes to the curriculum, transition programs, mathematics support outside the classroom and assessment strategies are all directed toward improving mathematics education. The innovations are diverse in nature. Examples of approaches to improving mathematics education are described below.

2.6.4.1 Professional Development

A great number of studies focus on the development of in-service teacher education and professional skills. Examples in mathematics include:

- supporting teachers to implement problem solving approaches (Anderson 2005);
- involving teachers in research projects to build connections between research, theory and practice (Nally 2005);
- mentoring teachers through different approaches in their own classroom (Kensington-Miller 2005);

- acquisition of ICT skills (Fitzallen 2005);
- development of novice teachers through exploration of the choices made by experienced teachers when electing to illustrate applications of procedures and exemplify concepts (Bills & Bills 2005);
- teacher preparation to enhance teachers' ability to learn from their experiences, encourage the importance of lifelong learning and improvement in teaching mathematics (Carroll 2005) and
- development of teacher practice, by students learning through their reactions to each others' practice of providing clear explanations, showing mathematical procedure-method, selection of individual work to check their understanding and the construction of new concepts (Kaur 2007).

2.6.4.2 Understanding Student Thinking

Many researchers focus on understanding or identifying the nature of students' thinking or conceptual understanding of mathematics. Examples include: examining how students make use of CAS in examinations (Ball & Stacey 2005); developing a taxonomy of student behaviour (Geiger 2005) and how vector calculus is taught with Maple to undergraduate students so as 'to understand the practices and meanings that characterise student and teacher behaviour in the classrooms' (Blyth, Clark & Labovic 2006, p. C197). Research focusing on identifying the nature of student misconceptions or errors in mathematics is covered in Chapter 3. Knowing how students think mathematically provides a basis for the development of strategies for facilitating the type of mathematical thinking required.

2.6.4.3 Discourse and Communication

Discourse has been used to engage students in productive talk about mathematics. Sherin, Mendez and Louis (2000) identified three aspects of this: explaining, building, and going beyond.

A review of *the MERGA 28-2005* (Mathematics Education Research Group of Australasia) conference papers revealed a number of papers in the context of curriculum reform that involved examining and changing the nature of discourse in the mathematics classroom, typically at the primary school level. By inference these raise questions as to the impact of discourse in tertiary mathematics teaching. Examples include:

- collaborative research partnerships examining the nature of teacher discourse, the impact of teachers' belief on discourse, enacting reform-oriented mathematics teaching particularly in relation to using the concepts and tools of discourse with a view to improving mathematics instruction (Herbel-Eisenmann 2005);
- the development of mathematical inquiry and discourse. Discussed in the context of the reform classroom, they examine how communication and discourse influences students' engagement in mathematical practices, increasing student autonomy, deepening collective responsibilities and the development of mathematical thinking and practices (Hunter 2005) and
- focusing on discourse and appropriate language in the New Zealand Numeracy Project. This helped non-English speaking background students and promoted mathematical language and thinking in order to facilitate the understanding of higher mathematics (Woodward & Irwin 2005).

2.6.4.4 Innovation in the Classroom

Many innovations relate to making changes in the classroom and introducing pedagogical change. Examples of this include:

Asking Students to Solve an Open Problem

To foster a 'smooth' approach to proofs, productive and creative thinking and raising motivation (Furinghetti, Olivero & Paola 2001).

Teaching Knot Theory

This was taught to primary and high school students in Japan to improve their sense of space, increasing their involvement in mathematical activities. Yanagimoto et al. (2007) drew knots to visualise images of motion and students were interested and surprised by finding mathematics in the knots of their life.

Mathematical Games

These have been used to develop ability in applying concepts and skills, engaging students, constructing new knowledge, encouraging social behaviour and self-analysis, and to foster mathematics communication as well as motivation (Abu Bakar, Osman & Mohd Shariff 2007); and engaging students to construct mathematical ways of thinking (Booker 2007).

Using Video-Recorded Lessons

This encouraged students to reveal their reasoning and creative thinking (Furinghetti, Olivero & Paola 2001). They also documented that much research supports the use of open problems to encourage proving.

Adoption of Understanding by Design (UbD)

This involves a framework to engage students in exploring, so as to improve transfer of learning, to increase the ability to apply knowledge in new contexts instead of rote learning, to deepen students' understanding of the content and to increase their ability to provide explanations of knowledge (Sandi & Miin 2007).

Compulsory Tasks Applying Mathematics within a Context

To improve transfer a variety of approaches have been tried. For example, Jackman, Goldfinch and Searl (2001) introduced compulsory tasks to improve the ability of science and engineering students to apply mathematics within a context. They found that it improved students' attitude to mathematics and also their ability to apply mathematics to in-context questions.

Some innovations may involve both technology and other changes. For example:

Multidisciplinary Approaches with Technology

Barry and Webb (2006) used an integrated multidisciplinary approach to teach numerical methods to first-year engineering students. In this case they combined physics and mathematics and the use of Matlab. They focused on improving deep learning, on motivation and on learning to solve problems quickly.

Computer-Assisted Learning, Peer Tutoring and Flexible Delivery Initiatives
This approach was used to improve problem solving skills and technical communication skills, in a first-year engineering mathematics course (Coutis, Farrell & Pettet 1999).

Interactive Digitised Video
Situating digitised video graphs representing motion within learning calculus provides situations where students not only interpret graphs created by technology but where they must create the graphs themselves (Boyd & Rubin 1996).

2.6.5 Provision of Learning Resources

One way to help students to overcome the barrier between high school and university level mathematics is to provide additional learning resources. These may take form of textbooks, worksheets and manuals. Kajander and Lovric (2005) found that incoming students who, prior to coming to university used a review manual containing fully worked mathematics problems, did better than those who did not use it.

Audio-tapes, with a booklet of accompanying notes, were used by Rees, Atkin and Zimmerman (2005) for engineering students to replace four conventional lectures on vector analysis. Materials were chosen with explanations on known troublesome topics, such as the differences between vector and scalar operators. Examples relating to engineering were included, for example fluid flow. A variety of activities were built into the resources including: listening, reading, thinking and writing exercises. One of the aims was to increase the autonomy of learning by ‘enabling students to work through material at their own pace’ (p. 358) as students who enter university have different backgrounds and abilities. The researchers also indicated that ‘students thought that the audio-tape package adequately replaced four conventional lectures’ (p. 366).

Increasingly, learning resources are being made available through technologies and the World Wide Web. These are discussed in the next section.

2.6.6 Technology Based Innovations

Different types of innovations have been used to promote various learning outcomes, whether the outcomes are the enhancement of students' understanding, motivation, or attitudes towards mathematics. Zevenbergeh (2001) considered technology to be a 'pedagogical tool' enhancing learning.

> Technology has been seen to enhance learning through two complementary features. In the first place it reduces the tedium of boring and mindless calculations and second (but not unrelated) is that it allows students to explore mathematics (Zevenbergeh 2001, p. 23).

The literature suggests that these two features can be expanded and reclassified to include student motivation, communication and learning resources.

Many of the technology based innovations mirror non-technological approaches.

2.6.6.1 Student Motivation

Technology provides several avenues for improving student motivation. These include reducing the tedium of calculations, real world applications, web objects, providing positive feedback, and playing.

The Reduction of the Tedium of Calculations

This is typically done through computational packages or graphics calculators. The adoption of these technologies is often associated with an ability to pose more realistic problems that, in turn, are associated with increasing student motivation to learn. It also leads to a better understanding of abstract and complicated mathematical concepts, as students concentrate on mathematical concepts, making conjectures and realising mathematics (Yang 2007).

Real World Applications

The use of 'real world' applications often motivates students to approach to grips with the underlying mathematical content (Martinez Luaces & Guineo Cobs 2002).

Web Objects

Using web objects such as bank sites and interactive bank calculators to establish a connection between mathematics in the classroom and in the real world can enhance students' confidence in their mathematics as well as their ability to transfer data through the internet. The use of bank calculators enabled students to be analytical and critical (Kin 2007).

Prompt Feedback

The provision of timely feedback is often perceived as motivational. For example, Jacobs (2005b) implemented an online assessment system with automated marking which provided students with prompt feedback. In this system, if students answered questions incorrectly, they were presented with a test containing new questions, similar to the incorrectly answered ones. This procedure continued until the student correctly answered all questions in the current iteration of the process. Re-testing in this manner was found to lead students to further analysing the appropriate online module before answering the new iteration of questions. Evaluations by students indicated that they gained 'enjoyment, understanding of concepts and ease of use' (Jacobs 2005b, p. 140).

Playing

Mavrikis and Macciocia (2002) described a web-based authoring tool and tutoring environment that allows members of staff to develop material that students can use as an additional support to their conventional studies. Java applets were used to create interactive learning tools. They described a prototype which allows students to 'play' with vectors. For instance, they can change the size of a vector, its direction and visualise its unit vector. The approach is constructive and engages students in learning because they can discover and make use of the materials.

2.6.6.2 Communication and Interaction

Technology is increasingly being used to provide an effective means of communication. Indeed the second case study in this thesis examines and evaluates a number of communication tools. Examples of the use of technology in a communication role to improve aspects of mathematics education include the use of *MSN Messenger* for distant students and the use of *hypervideo* to support effective learning. Loch and McDonald (2007) investigated the use of MSN Messenger, a free chat client, as a handwriting tool for two first year mathematics-based courses for distant students. Instructors and students could directly write, post and edit mathematical notations, graphs and diagrams in synchronous tutorial sessions. They found that students:

> … were comfortable reading what was written in electronic ink … they used the chat outside the tutorial hour to discuss further problems and to help each other (p. 12).

Chambel and Guimarães (2002) described the use of *hypervideo* in supporting effective communication, transmission and learning of mathematics concepts, because:

> Video treats mathematical concepts in ways that cannot be done at the chalkboard or in a textbook. They use live action, music, special effects, and imaginative computer animation. Video makes it possible to transmit a large amount of information in a relatively short time … The video presentations are an important step into more powerful learning materials (pp. 80 & 89).

2.6.6.3 Learning Resources

The use of websites to provide learning materials for students is also increasing in prominence. These websites vary in form and structure and this is discussed in Section 2.7. Reasons for the development of websites vary from providing relevance, animating concepts, testing university or college preparedness, to addressing issues of inclusiveness in mathematics education. Examples of what is included at various websites follow.

Theory

The website *Theory for the Calculus PHobe* provides theory to explain limits and continuity, and finding derivatives (http://www.calculus-help.com/funstuff/phobe.html). A flash animation is used to deliver 'theory' which starts with a real life scenario and morphs to the mathematical representation as shown in snapshots of Figure 2.3.

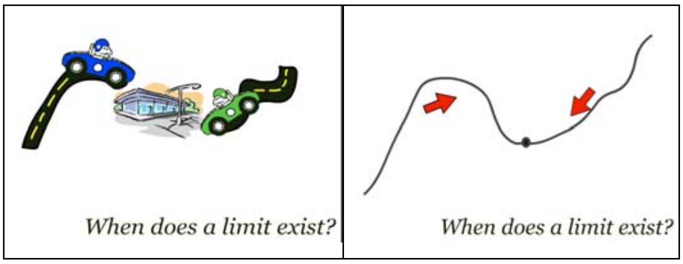


Figure 2.3 Animation of Limit of a Function

Relevance

The website *Linear Algebra close to Earth* at the University of Ottawa provides students with resources on systems of linear equations, vector spaces, matrix algebra, determinants, eigenvalues and eigenvectors. It was developed to show students the relevance of mathematics in other areas of study (http://aix1.uottawa.ca/~jkhoury/linearnew.htm).

> Matrices provide a theoretically and practically useful way of approaching many types of problems including: Solution of Systems of Linear Equations, Equilibrium of Rigid Bodies (in physics), Graph Theory, Theory of Games … (http://aix1.uottawa.ca/~jkhoury/matrices.html).

Tests of Mathematics Readiness

Some websites are designed to test a general readiness for mathematics. For example, the website *Internet Resources for Mathematics Students* provides text-based lessons and tests of mathematics readiness for pre-calculus (http://www.langara.bc.ca/mathstats/resource/onWeb/precalculus/index.htm).

> The test consists of a collection of multiple-choice questions involving basic mathematical skills, algebra, geometry, trigonometry, reading, and problem-solving (http://www.langara.bc.ca/admission/tests/mdt/).

The University of New Brunswick provides pre-assessment tests for students with answers rather than worked solutions (http://www.math.unb.ca/ready/exercise.html).

The website *maths online for school and distance learning* provides a gallery of multimedia for learning (http://www.univie.ac.at/future.media/moe/). This website contains dynamical diagrams, self-made puzzles, and interactive tests to assist students to determine their general mathematics readiness.

Tests of Readiness for Mathematics within a Discipline Context

The website *Self-instructional Mathematics Tutorials* is aimed at increasing students' success (http://cstl.syr.edu/fipse/MathReview.html). It provides tests for chemistry, economics, political science and psychology with questions phrased in a discipline specific manner. Having completed the test, the student can see from the result a diagnosis of what topics need to be reviewed. This self instructional approach allows students access to text-based mathematics tutorials and reviews, and a glossary of terms. Interactive versions have not been developed as yet.

Textbooks Online

Many websites have the appearance and the function of a textbook, with the addition of hyperlinks to further definitions or theory such as the website *Calculus Index* (http://web.mit.edu/wwmath/calculus/index.html)

> It has been designed so that anyone with a Web browser and a text book can use it (http://web.mit.edu/wwmath/calculus/ispath/ispath.html).

It provides theory, and definitions in textual form (Figure 2.4). As yet incomplete, this website includes a calculus independent study path, a calculus summary, limits and differentiation.

Please see print copy for figure 2.4

Figure 2.4 The Calculus Index Website

Writing in Mathematics

Various websites or other technology resources focus on online communication (Section 2.6.6.2), but some focus specifically on the writing of mathematics to communicate to the reader. For example, Ratliff (1995) found the need to improve writing so that his students could complete projects. Ratliff wanted

> … the students to work on difficult and open-ended problems … to improve their mathematical communication skills by working in groups and by writing their results in self-contained … giving the students the opportunity to be creative in their papers (http://www.wheatoncollege.edu/Academic/academicdept/MathCS/Faculty/tratliff/writing/aux/ume.html).

History of Mathematics

Some authors have suggested that curricula need to be modified to include courses in the history and philosophy of mathematics (Thompson 1992). Several websites facilitate the teaching of mathematics through a historical approach. For example, Joyce (1994) discussed Euclid's *Elements* and his construction of the logical foundations of mathematics (http://aleph0.clarku.edu/%7Edjoyce/mathhist/mathhist.html).

Furinghetti (2000) argued that the integration of history in mathematics is a source of motivation. Furinghetti exemplified the use of a historical approach with students becoming aware of different aspects of definitions such as

- *logical* (a definition can always be eliminated);
- *epistemological* (a meaningful definition cannot be eliminated);
- *didactics* (… definitions may be something to construct together with students … definitions which are essential to prove theorems and to construct a theory) (p. 49).

By examining the definitions over historical time, students become aware of not only the linguistic aspects of definitions, 'but also aspects linked to proof (inferential rules and axioms)' (Furinghetti 2000, p. 49).

As can be seen from Figure 2.5, historical websites also relate closely to particular cultures (http://library.thinkquest.org/22584/emh2000.htm).

Please see print copy for figure 2.5

Figure 2.5 A Historical Website

Some of these websites are more inclusive than others. The website (http://en.wikipedia.org/wiki/History_of_mathematics), for example, includes mathematical history embracing Ancient Greece, Mesopotamia and Egypt, as well as Arabia and other Islamic and non-Islamic countries.

Cultural Inclusivity and Empowerment

Closely associated with the historical accounts of mathematics which show mathematics development occurring in many cultures, there are websites that address the issues of being inclusive, for example, including women in the study of mathematics by illustrating ‘the numerous achievements of women in the field of mathematics’ (http://www.agnesscott.edu/lriddle/women/women.htm). These types of websites address an important educational issue of empowerment by including women and other minorities or cultures. They are also associated with developments in educational theory regarding transformative learning or emancipatory constructivism (Mezirow 1990), wherein ‘… students will begin to see each other as equals regardless of race, class, ethnicity or gender’ (Adamo n.d., p. 2).

These websites have been used to redress beliefs that preclude students from engaging in mathematics.

> In Mathematics, more than any other field of study, have we heard proclamations and statements similar to, “The Negro is incapable of succeeding.” Ancient and present achievements contradict such statements. One of the purposes of this website is to exhibit the inaccuracy of those proclamations by exhibiting the accomplishments of the peoples of Africa and the African Diaspora within the Mathematical Sciences (http://www.math.buffalo.edu/mad/index.html).

Anxiety, Phobia about Mathematics

The Le Moyne College provides tips on how to deal with math anxiety http://www.lemoyne.edu/academic_advisement/academic_support_center/mathanx.htm) The website *Mathematical mental representations* gets students to identify their reactions to mathematics by completing an interactive questionnaire on their attitude toward mathematics and then provides an explanation of reactions phobic avoidance, reparation, repression, introjection, projection and narcissism (http://perso.orange.fr/jacques.nimier/mathematics.htm).

The growth of these websites suggests that they are perceived as useful for students and teachers of mathematics. They also represent a transfer of traditional literature to the new medium. For example, Tobias (1993) in *Overcoming Math Anxiety* examined how to improve mathematics education by accommodating different learning styles. Evaluation of the impact of the various sites is not so readily available. While it is possible to evaluate using criteria such as *increasing number of people accessing the site*, evaluation as to the impact on learning of such websites is more difficult:

> While there was some evidence of impact on more able pupils, none of the teachers were able to quantify this impact but all praised NRICH as a very valuable resource (Jones & Simons 1999, p. 2).

2.7 How to Use Information Communication Technologies in Mathematics?

In integrating information communication technologies (ICTs) into mathematics teaching, Oldknow and Taylor (2000) referred to three types of useful software with a set of questions for mathematics teachers wishing to evaluate them:

> **Pedagogical:** can it be used to help teach content, to develop concepts, to increase knowledge, to improve understanding, to practise and reinforce skills?
> **Mathematical:** can it be used to compute results, to produce tables, to draw graphs, to solve problems, to manipulate expressions, to compute statistics?
> **Organization:** can it help me to produce materials more efficiently, to keep records, to manage time, to communicate with others, to find resources? (p. 12)

While this framework has been used to organise the remainder of this chapter, there is a deeper issue that has been identified in the literature, namely the status of visualisation, as a form of thinking mathematically that can be facilitated by ICTs.

2.7.1 Pedagogical Tool and/or Way of Thinking

Borba and Villarreal (2005) in answering the rhetorical question: 'why another book about computer technology?', points to three issues – while computers have the potential to change education, they have not as yet had the impact that they could have; technology continues to develop and is in this sense 'new' and finally, computers have the potential to change how students think and learn. Two styles of thinking mathematically have been identified: thinking algebraically with an emphasis on algebraic solutions and the formulation of explanations, conjectures and refutations with formulae and equations; and thinking visually, where graphical information and solutions, without the need for algebra, are accepted (Villarreal 2000). The production of mathematics and the pedagogy of mathematics have been dominated by algebraic approaches (Borba & Villarreal 2005), however there is some recognition that visual forms of representation are legitimate aspects of reasoning and learning, not just as heuristic and pedagogical tools (McLoughlin 1997). As Dreyfus (1991b) said:

> … visual reasoning in mathematics is important in its own right … therefore we need to develop and give full status to purely visual mathematics activities … one goal is balance … in order to achieve balance, visual reasoning needs to be given equal status and attention as algebraic reasoning (p. 46).

Visualisations are viewed as important for facilitating a deeper level of mathematical understanding. For example, Edwards and Edwards (2003) used *Mathinsite* to provide visualisation in order to provide a deeper understating and improve the learning process of mathematics for engineering students. They indicted that most students achieved 'a better insight into the particular aspects covered' (p. 101).

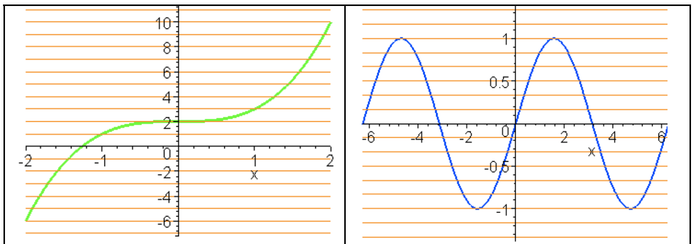
An analysis of current web-based learning resources would perhaps erroneously suggest that visualisation is the dominant pedagogical tool in mathematics. The learning resources appearing on the web overwhelmingly focus on visualisations of one form or another. Presmeg (1986) defined ‘visual image’ as ‘… a mental scheme depicting visual or spatial information’ (p. 42). Presmeg also defined ‘mathematical visuality’ as

> A person’s mathematical visuality is the extent to which that person prefers to use visual methods when attempting mathematical problems which may be solved by both visual and nonvisual methods (p. 42).

Presmeg (1986) identified five types of visual imagery in her students (1) *Concrete, pictorial imagery* or picture-in-the-mind; (2) *Pattern imagery* (pure relationships depicted in a visual-spatial scheme); (3) *Memory images of formulae*: Visualisers typically “saw” a formula in their minds, written on a blackboard or in their notebooks; (4) *Kinesthetic imagery* involving muscular activity, e.g. fingers, walking; and (5) *Dynamic or moving imagery* (pp. 43-44). Two of these forms, concrete images and dynamic imagery are readily produced in and evident in ICT.

Concrete, pictorial imagery

An example of a concrete pictorial image is provided on the *Inverse function* webpage, (http://xserve.math.nctu.edu.tw:16080/people/cpai/lab91_1/suppl/suppl_inverseFunction/suppl_inverseFunction.html), where a static image is used to illustrate the use of a horizontal line test to check whether a function is one-to-one (Figure 2.6). If the line only cuts the graph once it is considered one-to-one.



Line test shows inverse of function exists | Line test fails

Figure 2.6 Line Test for a One-to-One Function

Dynamic websites

One of the areas that has been greatly enhanced or even made possible through computer technology is the provision of dynamic or moving images to illustrate or create mathematical thought. The following example on parabolas, Figure 2.7, dynamically illustrates how to graph a tangent (not readily seen in the static image). The movie shows that as the point rotates on the unit circle through the four quadrants, the actual nature of the tangent function and the discontinuities in the graph of the tangent become evident (http://clem.mscd.edu/%7Etalmanl/MathAnim.html).

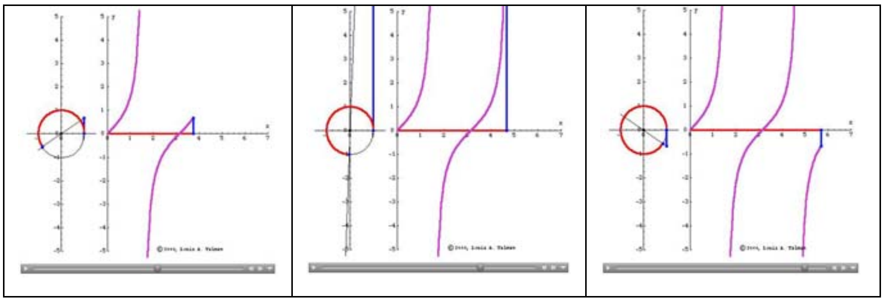


Figure 2.7 The Tangent Curve

The ideas for other dynamic websites such as those on the website *Mathematica Animations for Teaching Mathematics* represent a replacement of physical activities that may have been used to illustrate a mathematical property (http://www.calculus.org/Contributions/animations.html). The animation of the *Focus of a Parabola* in Figure 2.8 shows:

> … the graph of a parabola and light rays coming in from above, together with the reflection of the rays. Each of the reflected rays hits one particular point, which is the focus of the parabola. This experiment can be done with a parabolic mirror, at least one laser pointer (two is best), and chalk dust (so that the path of light of the lasers can be seen), and is more fun for the students. If you have these items available, consider using them rather than this animation.

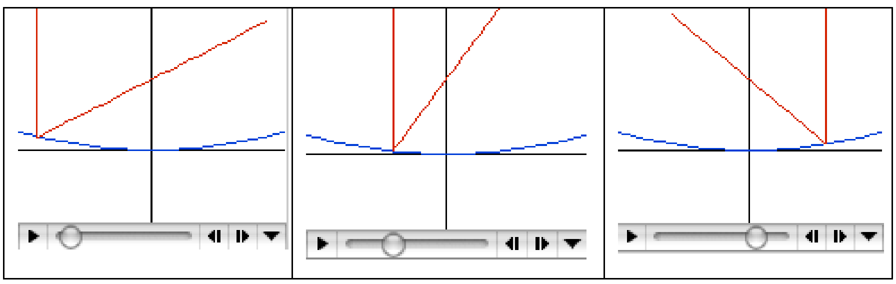


Figure 2.8 Animation of Parabola Function

Many of the dynamic visualisations focus on the 'what-if' of visualising which allows students to see what happens if they change something. For example, on the website

Graphics for the Calculus Classroom (http://www.ima.umn.edu/~arnold/graphics.html), Arnold (1997) developed graphical demonstrations that used the animated GIF format (Figure 2.9) for calculus topics such as differentials and differences, a trigonometric limit and the intersection of two cylinders. The following illustrates how the website treats exponential function:

> Students are often puzzled by the appearance of the number e, which is given above (to 35 decimal places). A simple explanation of its origin arises from the fact that e is the only number for which the tangent to the graph of $y = e^x$ through the point (0, 1) has slope exactly 1. The important result that the function $f(x) = e^x$ is its own derivative follows easily from this fact and the elementary laws of exponents. This animation here simply shows the graph of $y = a^x$, but with varying a.

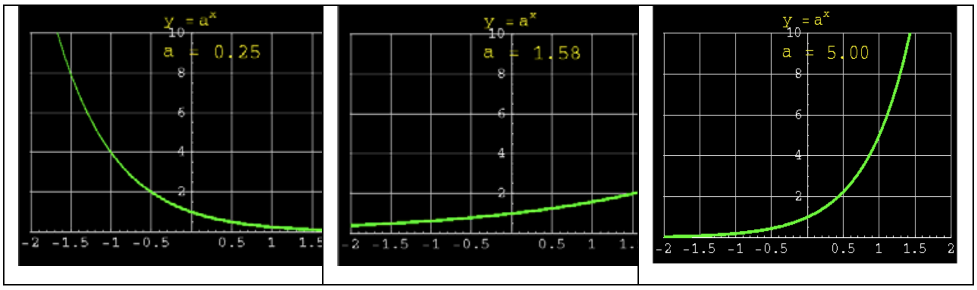


Figure 2.9 Animation of $y = a^x$ Function

Spreadsheet Scripts are another example of the use of dynamic visualisation and are often used to explore mathematical concepts through the answering of 'what-if' type questions. Examples of this are scripts for functions (Boland 2002). They have been used to increase student insights (Arganbright 2006), to understand mechanical design, the dynamics of machines, fluid dynamics and thermodynamics (Mays, Glover & Yearwood 1996), to visualise optimisation problems (Das & Hasi 1996), and to model growth and harvesting (York & Arganbright 1997).

There has been a shift to recognising visualisation processes as a legitimate form of thinking and as a valuable pedagogical tool. Bishop (1989) concluded:

> There is evidence that there is value in emphasizing visual representation in **all** aspects of the mathematics classroom. At the same time the highly individual and personal nature of the visualization process does need to be born in mind by mathematics educators (p. 14).

The distinction between visualisation and reasoning is often emphasised and debated. Jones and Bills (1998), for example, remind us that visualisation can be an aid to reasoning but can also be misleading. Perhaps in this context it is useful to remember that not all student reasoning arrives at the appropriate conclusion.

2.7.2 Mathematical Tools

Many universities use commercial packages such as *Maple*, *Mathematica*, *Matlab* or equivalent freeware. These packages allow students to both visualise and compute, and have a role as a mathematical tool which allows the solving of problems. For example, Barry and Webb (2006) integrated *Matlab* into a multidiscipline course. This allowed students to learn how to solve real life engineering problems. The use of such problems motivated students to understand both the mathematical content and the use of *Matlab*. Packages such as *Maple* have also been used to improve achievement for specific topics such as integration (Awi, Zainuddin & Uda 2007). There are also projects using *Mathematica*, such as the METRIC Maths Project which aims to smooth the transition to university mathematics by improving the mathematical skills and knowledge of entering students in science, engineering and economics
(http://metric.ma.imperial.ac.uk/new/html/index.html).

Spreadsheets also are used to find numerical solutions to differential equations and matrix inversions for solving systems of linear equations, to check integration via numerical integration (De Mestre 1996) and to undertake and simplify many mathematical calculations.

2.7.3 Organisation

To support online learning Oliver and McLoughlin (2001) stated:

> *The learning environment must be designed to enable novice learners to gain knowledge within a supportive framework* (p. 149).

They pose the question ‘What forms of teaching assistance are likely to create motivating contexts for learners?’ (p. 150) and they look towards supporting collaborative and social learning environments, enabling communication between learners. In this thesis, it has been assumed that students would be assisted by aligning the learning support resources with the content of the subject. In a technological sense the use of organisation strategies is clearly evident in the way mathematics learning resources are structured on websites. These websites could be classified as providing:

Indexes of Websites

Increasing in prominence is the use of websites to provide links to learning materials for students. One example of this is *A Catalog of Mathematics Resources on the WWW and the Internet* (http://mthwww.uwc.edu/wwwmahes/files/math01.htm), which has been made available by Maheswaran. Included in the index of this website are sub-classifications of resources, for example mathematics software or mathematics books and publication as a source for mathematical literature (Figure 2.10).

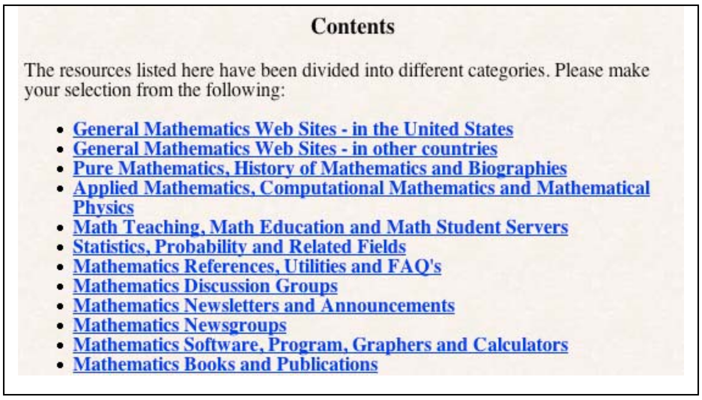


Figure 2.10 A Catalog of Mathematics Resources on the WWW and the Internet

Reasons for the development of websites listed varies from providing relevance, animating concepts, testing university or college preparedness as discussed in Section 2.6.6.3. These websites would be particularly useful for students engaged in identifying resources to assist their own learning. Students can use communication tools such as forums and chats or online debates to share these resources with others (Oliver & McLoughlin 2001).

Indexes of Topics

An example of this is provided by the *National Curve Bank, Math on the Web* (http://curvebank.calstatela.edu/home/home.htm). The index includes a mix of media, such as videos, animations, PowerPoint slides, for a range of topics, with little apparent structuring or connection between topics (Figure 2.11). Examples are taken from a review for calculus, pre-calculus and maths in science.

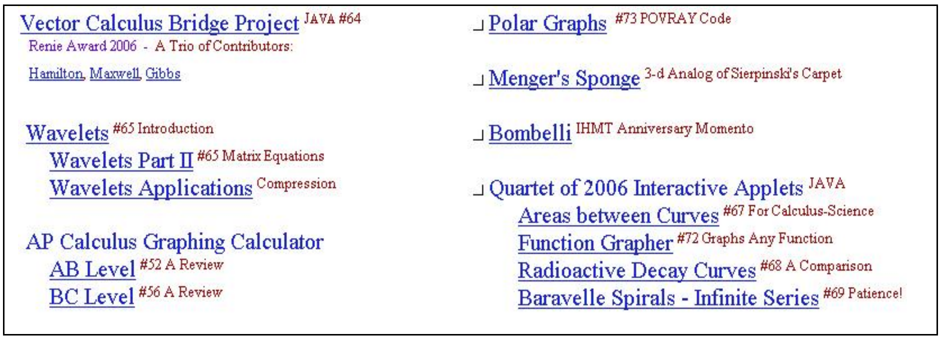


Figure 2.11 Math on the Web

Another example, the *Mathematics Animated* website, provided ‘little or no explanation of what the animations illustrate’ but was provided for knowledgeable instructors so they could use the movies with their students (Figure 2.12) ‘such instructors would already know what was going on and would provide their own explanations’ (Talman 2007, p. 1) (http://clem.mscd.edu/~talmanl/MathAnim.html).

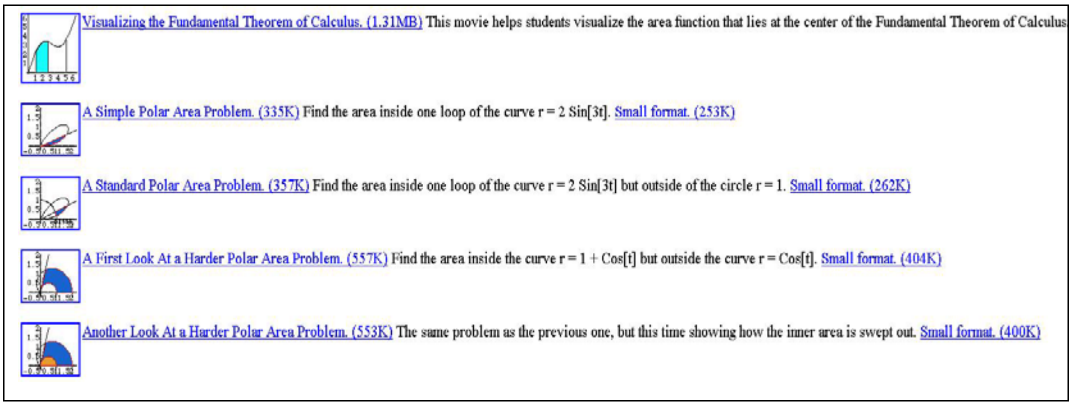


Figure 2.12 Mathematics Animated Website

Again, these websites are useful for students engaged in locating resources to support their learning, however in their search they may encounter many websites which are not particularly useful for their learning.

Structured Learning Resources

Structured learning websites provide complete resources for a subject or area, such as calculus. These websites may focus on one or many aspects of learning resources. For example, Jacobs (2005a) details a website of *online modules* using animation, visualisation and interactive graphs to maximise the comprehension of differential equations. The tools in the modules allow students to take control of their learning by encouraging them to explore, investigate and question the new concepts presented to them. A second example is provided by the website *STEPS, Statistics Education through Problem Solving*. This website is designed in the United Kingdom as resources to facilitate the learning of statistics. In contrast to the online modules, this website is not specifically set up as a course or subject.

> … a learning tool, leading students through hypertext-based tutorials on a wide range of statistics topics. For students doing Mathematics A, B and C these tutorials will cover much of the statistics in these courses … A typical STEPS module starts by presenting a realistic problem and then discussing the statistics that will be needed to help find a solution to the problem. The student is lead through the process of finding a solution. Throughout this process students can review the required statistical techniques and consult a glossary for definitions of the statistical terms. All modules have an accompanying student workbook available in Word format in which the student is expected to record results and conclusions. Some of the modules also include a tutor manual, also in Word format, which gives suggestions on how the module can be implemented in the classroom (http://exploringdata.cqu.edu.au/steps.htm).

In the context of this thesis, the organisation of learning resources was considered important. As Oliver and McLoughlin (2001) indicated some years ago, the task of identifying and documenting websites is a task that would tax ‘even the most enthusiastic teacher’ (p. 152). Had the orientation of the subject been problem solving it might have been appropriate to place emphasis on students identifying their own resources, however the orientation was the development of mathematical skills, with later subjects focussing on developing problem solving. For modern-day students, the time involved in the search for resources needs to be balanced by the time needed to engage with mathematical resources to develop mathematical skills. The provision of structured learning resources needs to be balanced against the need to develop students who as independent learners can find and utilise resources that support their learning. In this thesis, the emphasis has been competency with mathematical skills more than developing independent approaches in learning. For the purposes of this thesis, tertiary students' resources were selected and developed on the basis of their being necessary for the particular subject, and not extraneous to it. For ease of student access/referencing, learning resources are ordered initially according to the subject and later alphabetically (Chapter 4).

2.8 Conclusion

The literature review in this chapter focussed on the difficulties for students in making the transition from secondary mathematics to university mathematics. Two aspects of the transition were identified: transition in general to university life and its ways of studying and living; and the transition to the study of mathematics. It provided an overview of other attempts to address these transitional difficulties.

Prior to examining approaches to improving learning outcomes, the nature of learning outcomes was elaborated. There are many different outcomes, such as improved performance in tests, the demonstration of understanding, and improved motivation, among others. The nature of approaches to improving outcomes is examined. These approaches were: programs to assist the transition into university life, programs to assist the transition into tertiary mathematics subjects, specifically Bridging Mathematics and Enabling Mathematics, changes to the curriculum, assessment strategies, learning support programs, non-technology based innovations, provision of learning resources, technology based innovations such as using 'real world' applications that motivate students to come to grips with the underlying mathematical content (Martinez Luaces & Guineo Cobs 2002).

In the context of this thesis there is an interest in the role that technology can play in improving mathematics education. Technology has been proposed as the solution to many problems. In fact, it targets many outcomes. For example Jacobs (2005a) even considered the use of online assessment as a barrier to plagiarism. Technology is not, however, a panacea to cure all ills and there remains much debate about its use.

There is discussion of the perceived limitations of some computer-based resources, particularly in facilitating higher levels of learning, as for example, described by Bloom et al. (1956). Beevers and Paterson (2003) stated:

> There is plenty of evidence that these [mathematics] basic skills can be practised on-line by the student whereas it is doubtful with the present tools available that higher level skills involving proof and modelling can be taught adequately using on-line systems (cited in Foster 2003, p. 145).

Further, there is evidence that the impact of computer-based resources is not the same for all students. Alajääski (2006) investigated students' attitudes towards learning mathematics and statistics within an eStudy approach.

> eStudy is self-paced, asynchronous learning accessed via the Web. Learners can choose to launch the offering at any time, and can then proceed at their own pace (http://supprem.unige.ch/glossary/_show_def_oil.php?id=443).

Overall, Alajääski found that negative attitudes towards eStudy had decreased by the end of the course. However, the negativity of some subgroups, including students with a weaker mathematical background, increased. The study does not indicate whether eStudy increased the mathematical ability of the students.

Two issues that are often raised with the use of technology are the affordability for students and the frustration that many students experience while trying to use it. Students need support and lack of support and suitable planning can lead to disappointment rather than fascination (Stewart 2005). Technology based methods are not always found to be better than traditional ones. For example, Acelajado (2007) used an experimental group using the internet to sketch the graphs of equations and a control group with traditional methods and found no difference in performance.

Despite these difficulties, a number of technological solutions have shown great promise and some of these will be examined here.

In the next chapter, the learning environment for engineering students undertaking an introductory mathematics subject at a tertiary institution is described. Using the classification of ways to improve learning that has been developed in this chapter, the major learning resources available to the students in a first year calculus subject are identified and documented in preparation for the development, implementation and evaluation of additional technology based learning resources.

Chapter 3

Local Context and Baseline Skills

Tell me and I will forget,
Show me and I will remember,
Involve me and I will understand!
Attributed to Confucius

3.1 Methodology

In this chapter the scene is set for the first case study, which involves the design, development and implementation of video learning resources delivered over the World Wide Web (WWW) to students enrolled in the subject MATH141. This is a calculus subject, with the students predominantly undertaking engineering degrees.

The data used to describe the local context and identify baseline issues in mathematics for this student group are primarily from secondary sources. They have been obtained by accessing a large number of internal documents. Data gathering has also involved accessing background data such as failure rates from the following sources.

- Evaluation reports prepared by the Chair of a Faculty Education Committee working party called QUALITY101. This working party, formed in 2004, has been seeking strategies to improve faculty learning outcomes. This has involved a change evaluation conducted with students (Section 3.2.4) and a next step interview conducted with lecturers (Section 3.2.5). As part of that process, reports were issued to form an evidence base for further educational developments.

- Change evaluation for 2006 and 2007, with additional questions about the video resources developed for the MATH141 subject.
- Extracts from reports regarding background data such as failure rates. Only the Chair of the committee, who prepared the report, and the lecturer concerned have access to the full report, including such items as evaluation of the lecturers by the students, which are confidential; but background material that was prepared by the committee, such as failure rates and grades, have been made available.
- Funding applications that have been prepared based on the subject evaluations.
- Internal reports analysing the outcomes of educational initiatives such as the PASS program, the progress of opportunity students, the progress of students entering university from Enabling Mathematics and the progress of students through a sequence of three mathematics subjects.
- Summary data regarding grades for mathematics subjects.
- Data allowing the analysis of entry levels skills and performance in subject assessment.
- Interview and mid-session survey data collected from students and subject to a separate ethics application (no. HE06/021) by the researcher (Chapter 5).
- Interviews and email requests for information from lecturers about Bridging Mathematics and Enabling Mathematics, which prepare and provide entry for some students to MATH141.

3.2 Local context

Innovations are introduced into a specific context and so in this chapter use is made of the method called *thick description*, a term adopted from the philosopher Gilbert Ryle.

> Ryle pointed out that if someone winks at us without a context, we don't know what it means. It might mean the person is attracted to us, that they are trying to communicate secretly, that they understand what you mean, or anything. As the context changes, the meaning of the wink changes (http://en.wikipedia.org/wiki/Thick_description).

Understanding why innovations are successful or otherwise requires in part an understanding of the need for the resources and the other options that have been tried or are available to students. In order to understand the context for this study, it has been considered prudent to examine:

- the reason the case study was selected,
- baseline data regarding pass and failure rates for the subject selected for intervention,
- baseline subject evaluations of the selected subject by the QUALITY101 team,
- the assumed and recommended knowledge for the subject,
- the curriculum and pedagogical approaches,
- approaches to assessment,
- transition programs to facilitate entry to both the university and to mathematics,
- learning support on offer to the students,
- findings from entry level skills tests and
- the specific nature of deficit skills.

3.2.1 Improving Faculty Outcomes

Since 2003, the Faculty of Informatics at the University of Wollongong has had a Faculty Education Committee working party called QUALITY101. The role of QUALITY101 has been to investigate strategies for improving learning outcomes for students in targeted classes (Porter et al. 2003). Classes that were targeted were predominantly first year subjects that had high failure rates. The lecturers or coordinators for these subjects were co-opted as part of a process that involved conducting *next step* interviews with lecturers to ascertain their thoughts as to what strategy they would like to implement in an effort to improve outcomes and a change evaluation with students (Porter 2005c). The work of QUALITY101 was treated as a research process as well as an educational development process. Ethics clearance was obtained to undertake the work. Based on the data gathered from students and lecturers, together with historical data, a report was written by the Head of the Committee, the principal supervisor of this thesis. This report was returned to the lecturers suggesting strategies that could be tried to improve outcomes.

The author of this thesis was included as a researcher on that ethics application, as were the members of the QUALITY101 team and the lecturers themselves, as participant-researchers and, as such, was able to access:

- change evaluation forms and modifications used to evaluate 100 level subjects in mathematics, statistics, computing and engineering,
- reports which lecturers allowed to be used by the QUALITY101 team,
- applications for funding that made use of the data collected and
- extracts of historical data from reports where the substance of the report remained confidential.

3.2.2 Baseline Data: Failure Rates

Most first-year engineering students at the University of Wollongong take a six-credit mathematics introductory subject MATH141 (Mathematics 1C Part 1) in the first session and a follow-on subject MATH142 (Mathematics 1C Part 2) in the second session. Engineering students go on to take a combined mathematics and statistics subject in their second year of study. Historically, the failure rate in both of these subjects is high. Table 3.1 shows that between 2000 and 2005, the failures rate for MATH141 ranges between 22.4% and 31.1%.

Table 3.1 Student Grades (Per Cent) for MATH141*

Year	N	Fail	Pass Conceded & Pass	Credit	Distinction	High Distinction
2000	155	23.9	43.9	21.3	5.8	5.2
2001	143	22.4	49.7	17.5	7.0	3.5
2002	177	31.1	47.1	14.1	5.7	1.2
2003	185	24.5	42.7	16.2	9.7	4.9
2004	207	28.0	43.5	13.0	10.1	5.3
2005	179	30.7	42.5	13.4	10.1	3.4

* Data Source: the University of Wollongong, Cognos Data Base, 16/10/2006

Passing MATH141 does not guarantee that students are well prepared. Students who pass MATH141 usually go on to the next subject MATH142, where failures over the period 2000-2005 range from 20% to 39% (Table 3.2).

Table 3.2 Student Grades (Per Cent) for MATH142*

Year	N	Fail	Pass Conceded & Pass	Credit	Distinction	High Distinction
2000	146	19.9	42.5	19.9	15.8	2.1
2001	127	33.1	39.4	15.0	7.1	5.5
2002	142	21.8	52.8	18.3	5.6	1.4
2003	164	29.3	39.0	17.1	11.6	3.1
2004	167	38.9	46.1	9.0	1.8	4.2
2005	149	29.5	48.3	15.4	5.4	1.4

* Data Source: the University of Wollongong, Cognos Data Base, 16/10/2006

Data were collected from the cohort of students enrolled in MATH142 in the Spring Session 2004. The marks students gained in MATH142 were correlated with marks obtained from the students' most recent successful attempt in MATH141 or the MATH141 equivalent subject (Figure 3.1). A Pearson correlation between the marks for MATH141 and MATH142 revealed a significant positive relationship ($r = 0.50$, $n = 164$, $p < 0.001$) between the mark obtained in MATH141 and the mark obtained in follow-on subject MATH142. However, the relationship predicting MATH142 marks given MATH141 marks is not strong. Indeed, the predictive value of MATH141 marks was very limited for marks below 65 ($r = 0.22$, $n = 108$, $p = 0.022$) but somewhat higher for marks 65 or more ($r = 0.58$, $n = 56$, $p < 0.01$).

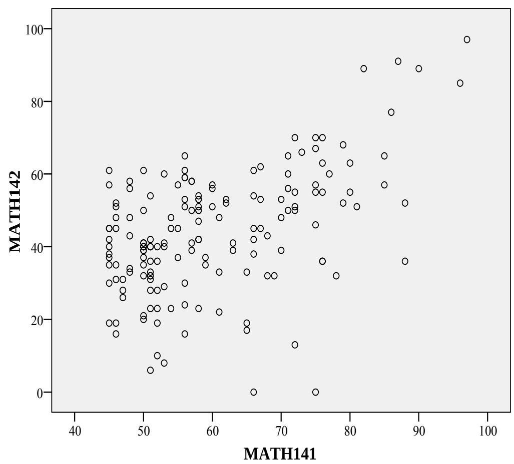


Figure 3.1 Scatterplot of the Final Marks for MATH141 and MATH142

3.2.3 Selection of Case Study Subject

The high failure rates in MATH141, the focus of this thesis, led to MATH141 being one of the subjects targeted by the QUALITY101 working party. In the funding application, Return to Mathematics Project, Porter (2007b) examined further the type of poor student outcomes that led to the instigation of a working party to investigate strategies for improving learning outcomes in the Faculty of Informatics. Based on the 2004 cohort of MATH141 and MATH142 students, Porter wrote:

> An example of the high impact that poor mathematics skills can have can be demonstrated by examining what happens to Engineering students when they attempt to complete a sequence of three mathematics subjects, MATH141, MATH142 and MATH283 (or equivalent subjects). In Autumn of 2004, twenty-eight per cent of the 207 students enrolled in MATH141 failed. After removing nine students enrolled in MATH142 who were study abroad, Science students and other MATH142 students who were not expected to complete the sequence of mathematics subjects, 158 students remained. These 158 students should have completed the three-subject sequence in 2005. As at Spring Session 2007, 65 per cent of the 158 students had completed the sequence.
>
> Number of Mathematics subjects taken to complete the three sequence subject
>
> | Number of Maths Subjects | Not complete MATH142 | Not complete MATH283 | Complete | Total |
> |---|---|---|---|---|
> | 2 | 8 | 7 | - | 15 |
> | 3 | 10 | 4 | 57 | 71 |
> | 4 | 5 | 7 | 23 | 35 |
> | 5 | 4 | 6 | 17 | 27 |
> | 6 | 2 | 2 | 1 | 5 |
> | 7 | - | 1 | 2 | 3 |
> | 8 | - | - | 1 | 1 |
> | 9 | - | - | 1 | 1 |
> | Total | 29 | 27 | 102 | 158 |
>
> Of the 65% of students completing the sequence,
>
> 1. 56 per cent completed in the minimum time (36% of the total number of students)
> 2. 44 per cent attempted 4-9 subjects to complete the three subject sequence.
>
> Of the 35% of students who had not completed the sequence,
>
> 1. 18 per cent (n = 29) had not completed the second subject in the sequence
> 2. 17 per cent (n = 27) had not completed the third subject in the sequence.

Following the change evaluation and next step interviews done by QUALITY101 in 2005, the subject MATH141 was identified as a suitable case study for the investigation of the role of technology in enhancing student learning outcomes. The provision of worked solutions was identified as a potentially useful learning resource after the evaluations and interviews conducted with students and lecturers of the MATH141 equivalent subject in 2004 and MATH141 in 2005. While the lecturer in the MATH141 equivalent subject was due to change, the primary lecturer in MATH141 was to remain the same. The timing of subjects also meant that the introduction of resources could occur six months earlier for MATH141 than for the equivalent subject. The coordinator of MATH141 was cooperative, even prepared to act as co-supervisor of this thesis and critic of the resources developed.

3.2.4 Change Evaluation

Analysis of the change evaluations for several subjects and associated reports (Porter 2005a) revealed that the primary intent of this survey was to ask students to evaluate the learning resources for their subject. Demographic questions ascertained the sex of the student, the location of study, and whether the student was a domestic or international student. Data related to their work practices were also gathered. Learning resources were then rated in terms of their usefulness in helping students learn and understand in their subject.

In 2004, students voluntarily completed the survey for the MATH141 equivalent subject on paper and in 2005, they completed it online in their e-Learning space WebCT. Instructions given to students were as follows:

> The primary purpose of this survey is to provide feedback that can assist in the development of the subject for future students. Some students attend lectures others choose to use the materials on the course Web Page and some use both. Some resources are more useful than others. The feedback of ALL students is valuable in this process (Change Evaluation Questionnaire 2005).

It was intended that the explicit recognition of different work patterns in these instructions would assist students in comfortably completing the questions on work practices (Table 3.3).

Table 3.3 Questions on Work Practices

Do you consider that you have completed the lecture component by

a. Attending virtually all lectures
b. Working through the online lectures on a regular weekly -fortnightly basis
c. Working through the lectures as they are required for assessment
d. Attending the lectures and working through the online lectures notes
e. Other

One question was asked about attendance on each of the two days of lectures
How many weeks would you have attended the … *day* MATH141 lectures

a. Did not attend … *day* lectures
b. 1-3 weeks
c. 4-6 weeks
d. 7-9 weeks
e. 10-13 weeks

How did you work through the tutorial sheet?

a. Downloaded the worked solutions to most tasks
b. Started completing the tasks and downloaded to complete them
c. Essentially completed all tasks in the tutorial
d. Essentially completed all tasks in the tutorial and checked them from the worked solutions

A sequence of questions explored how important each resource was for helping students to learn and understand mathematics. The resources included: lectures, lecture notes, textbook, student handouts, online lectures notes, tutorial classes, the tutor in tutorial classes, tutorials tasks, worked solutions for tutorials, assignments, the midterm exam and PASS program sessions. The question and options took the form, 'How important was *the resource* for helping you understand and learn MATH141?'

a. Not applicable – I rarely used *the resource*
b. I learned and understood very little from *the resource*
c. *The resource* was moderately useful for learning and understanding in this subject
d. *The resource* was extremely important for me in learning and understanding mathematics

When numbers permitted, the demographic data allowed an examination of the preferences for different types of resources on the part of different categories of students. Students were also asked what marks they obtained for their two Basic Skills Tests and the Mid-Session Test. This allowed a comparison of the grades students were receiving with the profile of grades for the entire student cohort completing the assessment in order to provide an indication of any response bias. It also allowed an assessment of whether the preference for resources was the same for students performing at different levels. In later change evaluation (2007), this was changed, asking students what grade the student *anticipated* for the subject, as some lecturers felt that students might be made to feel 'bad' by being asked about marks at the same time as asking about work patterns. It made assessing the impact of the resources more difficult in 2007.

An open-ended question was used to assess the academic integrity of the subject, this being a major issue confronting universities in Australia in the early 21st century. It asked, 'Do you consider that the assessment system is fair and that students basically earn the marks they get or is it rife with cheating or ...?'. A second open-ended question asked, 'How best can the MATH141 subject be improved?'.

An earlier form of the change evaluation (2004) asked students in a MATH141 'equivalent' subject:

> Are there types of resources or help provided in other subjects that would be useful to adopt in MATH161? What subject? What resources?

3.2.5 Recommendations for Improving MATH141

Recommendations for improvement could be located in several reports:

- the 2004 report on the MATH141 equivalent subject, MATH161 (Porter 2004),
- the 2005 report on MATH141 (Porter 2005b) and
- an associated grant application, *Fundamental Maths: Opening the Gates*, for funding for educational development (Nelson et al. 2005).

Students (n = 61) responding to the 2004 change evaluation for the MATH141 equivalent subject provided many suggestions as to how the subject could be improved.

> The dominant response made by 36% of students was that they would like resources, online/WebCT support, discussion boards, extra examples with solutions, practice exams, exam papers specific to this subject MATH161 not just the MATH141, online notes, quizzes online where you can do them to study, computer assignment like ECTE101 … (Porter 2004).

The second most cited suggestion by 23% of students (n = 14) was 'for additional teaching time, lectures, PASS sessions, help sessions at other times' (Porter 2004). The subject most cited as of potential interest was Physics, and this was typically in relation to online support.

The next step interview conducted by the QUALITY101 working party with the lecturer, clarified the lecturer's suggested strategies for improving MATH141 (Porter 2005b). These included:

> 1. Provide more learning resources relating to the Basic Skills Tests [BST], e.g. videos of worked solutions.
> 2. Next year give the analysis of the BST to all the MATH141 tutors and ask them to add assignment questions covering the worst topics.
> 3. Use the BST analysis in deciding which questions go on the weekly tutorial sheet - make sure the tutorials cover questions that students are known to be bad at.
> 4. After the BST in week 4 contact all students whose best BST is 10, or lower, and tell them that they are at risk of failing … unless they [improve their effort].
> 5. Liaise more closely with [Sub-Dean of Engineering] regarding engineering students.

Students were asked in the 2005 change evaluation 'How best can the MATH141 subject be improved?'

> The primary [student] response had to do with lecturing styles, the lecture notes and the inclusion of problem solving in the lecture. One lecturer was seen to provide the appropriate model for lecturing, including problem solving and useful notes … The tutorial system also had room for improvement with more time, more tutorials and probably better organization of the tutorials so that tutors did not get teaching to the one rather than assisting the many. One student may well have had the solution 'Having tutorials where everyone sits down and do it together' (Porter 2005b).

The repertoire of textual materials, resources, lectures, tutorials and assessments had been insufficient for some students.

Modifying curriculum fell outside the province of the committee and the change evaluation did not entertain it as a possibility, except through the open-ended question as to how to improve the subject. The focus has been, instead, on the development of additional learning resources to complement the existing subject resources. Interviews with the primary lecturer, a participant researcher, and an analysis of data collected through the change evaluation questionnaire (Porter 2004, 2005c) with students led to a recommendation that more video learning resources relating to the basic skills tests be provided (the data from this research is not yet published).

3.2.6 Assumed and Recommended Mathematics for MATH141

In 2007, the University Admission Index (UAI) to enter the Bachelor of Engineering course was approximately 80. The assumed knowledge was any two units of English plus mathematics, with a recommendation that students had taken physics, chemistry and HSC Mathematics Extension 1 (*2007 Undergraduate Handbook*, The Calendar Series, vol. 1, University of Wollongong, 2006). The important thing to note is that HSC Mathematics Extension 1 was only recommended, not required. Since 1997, the MATH141 subject was written assuming that students had a certain minimum competency in mathematics that is no longer the case. Engineering at the University of Wollongong has been unpopular for a number of years and the Engineering Faculty has had to recruit much weaker students than they would otherwise like to.

> The normal entry requirement for MATH41 is 'Either a mark of al least 65 in MATH151 OR in NSW HSC Examination: Mathematics - Band 2 or better' (*2007* Undergraduate *Handbook*, The Calendar Series, vol. 1, University of Wollongong, 2006, p. 483).

A Band 2 grade means a student:

- Correctly applies arithmetic and basic algebraic procedures
- Recalls many of the formulae and algorithms appropriate to the Mathematics course, such as Simpson's rule, the sine rule, and the cosine rule
- Graphs simple functions such as linear functions, quadratics, $\sin x$ and $\cos x$
- Finds derivatives of basic functions such as polynomials, $\sin x$ and e^x
- Uses the rules of differentiation such as the product rule
- Solves numerical problems involving the geometry of triangles (*Draft Performance Bands Mathematics,* http://www.boardofstudies.nsw.edu.au/syllabus_hsc/syllabus2000_listm.html#macedonianc).

The aim of the MATH141 subject at the University of Wollongong is to develop:

> Ideas, concepts and skills in mathematics, especially applied skills, for application in later subjects. Main topics covered are matrix algebra, determinants, vectors, and differential and integral calculus (*Undergraduate Handbook 2007*, Calendar Series, vol. 1, p. 483).

The aim of MATH142 at the University of Wollongong is to develop:

> Ideas, concepts and skills, especially applied skills, in mathematics for application in later subjects. Main topics covered are further calculus, differential equations, numerical mathematics, sequences and series of numbers and complex numbers (*Undergraduate Handbook 2007*, Calendar Series, vol. 1, p. 483).

3.2.7 Curriculum and Pedagogy

MATH141 is oriented toward the development of mathematical skills. The topics taught in MATH141 are: fundamentals, differentiation, matrices and determinants, integration, vector geometry and polar coordinates. For greater detail see Table 4.2.

MATH141 is structured so as to have two lectures of two hours each per week. The subject is broken into three sections and each has a different lecturer. One section runs for the whole session, two hours a week. The other two sections run for a half-session each, two hours a week. Rather than teaching topics sequentially, each of the two weekly lectures has a different lecturer and topic. There are thirteen weeks in the teaching session. Students also have a one-hour tutorial per week, with 16 students per class and eight engineering opportunity students per class, the students for the opportunity classes having been selected by the Engineering Faculty. All students in tutorial classes solve the mathematics questions using the whiteboards instead of pen and paper.

The primary lecturer is rated well in the change evaluation, with over 90% of students finding the lectures extremely or moderately useful. The topics lectured by the primary lecturer are: fundamentals, differentiation, polar coordinates and integration. The primary lecturer made available his *Learning - Teaching Portfolio* for describing his approach to teaching. He saw his role as facilitating student learning, creating an environment where students could maximise their learning

> … through appropriate assessments to evaluate student learning, student tutoring, the climate created when interacting with students.

He saw good teaching as being guided by feedback from students and colleagues, reflection on both the theory as well as 'what works'. Teaching he saw as 'a piece of ongoing research, driven by what happens'. He has learned from his colleagues

> - The importance of breaking up a lecture with examples for students to work through and 'hands-on' activity; giving them the opportunity to apply the ideas to see if they really understand them.
> - Asking specific students 'what did you get'.
> - Using true/false questions. This encourages the timid students to make a decision and participate in class.
> - Giving encouragement to students to try things on their own.
> - Sometimes it is better for students to listen to you explain a proof rather than for them to copy the proof down …
> - Sometimes you can lead students to making their own discovery of a theorem be asking them a sequence of questions that point in the required direction (Nelson 2007, pp. 9-10).

This lecturer had also learned to make time in class for students to work through their problems, allowing the lecturer to observe how students are tackling problems. Students are encouraged to have one-on-one discussion as they work on the problems. The lecturer no longer rushes to answer his own question and has learned to ask questions of students and attempts to stress the main points of the lecture (Nelson 2007).

The second lecturer taught algebra, matrices and determinants and the third lecturer taught vector geometry. While the actual second and third lecturers have changed from 2005 to 2007 the rating for these lectures has remained similar over the years, though different from the rating for the primary lecturer.

3.2.8 Lecture Notes

Students do not have a textbook for MATH141, but are provided with a list of reference books that they may consult. These include texts such as Anton (1995), Barry and Davis (2002), Thomas and Finney (2000), Fitz-Gerald and Peckham (2005) and others.

Over the years 2004 to 2007, students in MATH141 have been provided with a set of lecture notes. The lecture notes have theory, worked examples for completion in lectures, exercises at the end of each section, sample examination papers and answers for selected questions. Worked solutions are not provided for the exercises.

The lecture notes for MATH141 have varied over the years. In 2004 and 2005, lecture notes had no gaps for students to complete. In 2006 and 2007, some sections of the notes were modified to leave gaps for students to complete (Figure 3.2). For the topics on fundamentals, matrices and vectors, there are no gaps in the theory, in examples to be worked during lectures or for student exercises. For the topics of differentiation, integration, polar coordinates and polar curves, instead, there are gaps left for students to fill in, in the theory and in the examples worked in lectures, but not for the exercises for students to complete outside of class.

2004

2.1 FUNCTIONS

Definition 1:
For our purposes a **function** f is a rule or a procedure (or a "black box") which, for each number x in some subset A of $\mathbb{R}$, assigns a number $f(x)$ in $\mathbb{R}$.

Examples:

(1) $f(x) = c$ is called a **constant function**.

(2) $f(x) = mx + b$ $(m \neq 0)$ is called a **linear function**, with the special case $f(x) = x$ being called the **identity function**.

(3) $f(x) = a_0 + a_1x + a_2x^2 + ... + a_nx^n$ is called a **polynomial function of degree** n; special cases are the polynomial of degree one $(n = 1)$, the linear function, and the polynomial of degree two, the quadratic function.

The set A is called the **domain of** f, and is denoted by Dom f, and we indicate the situation by writing $f : A \to \mathbb{R}$. The domain is sometimes called the **source**.

Definition 2:
We say that two functions f and g are **equal** if and only if

$$\text{Dom}\, f = \text{Dom}\, g \quad \text{and} \quad f(x) = g(x) \text{ for each } x \in \text{Dom}\, f.$$

2007

2.1 Functions

2.1.1 The Basics

Definition: A function f is a rule which, for each number x in some subset $A \in \mathbb{R}$, assigns a (unique) number $y = (x)\ f \in \mathbb{R}$.

Definition: The set A is the set of all possible $x - values$ of the function f and is called the domain of f. The domain of f is denoted by Dom f.

Definition: The set of all possible $x - values$ of the function f is called the range of f. The range of f is denoted by Range f.

Examples

1. Given $f(x) = x^2$.
   Dom $f = \mathbb{R}$ or ____________ or ________________
   Range $f = \mathbb{R}^+$ or ________________ or ________________
2. Given $g(x) = x^2$. $x \geq 0$
   Dom $g = \mathbb{R}^+$
   Range $g = \mathbb{R}^+$
3. Given $h(x) = \frac{1}{x-3}$.
   Dom $h = \{x : x \neq 3\}$ or $(-\infty, 3) \cup (3, \infty)$ or $\mathbb{R} - \{3\}$.
   Range $h = \{y : y \neq 0\}$ or $(-\infty, 0) \cup (0, \infty)$ or $\mathbb{R} - \{0\}$.

Note that for the functions f and h, we choose the domain to be the largest set of x for which the function 'makes sense'. This is the ________________________ of f and h.

Definition: Two functions f and g are __________ if and only if ________________ and ________________.

Figure 3.2 Comparison of MATH141 Lecture Notes without and with Gaps in 2004 and 2007

There has been debate about the use of gaps in the School of Mathematics and Statistics at the University of Wollongong. In MATH142 there has been an oscillation in staff acceptance and rejection of the 'gaps' in lecture notes. In MATH142 in 2007 the gaps that were present in 2006 for the topics: complex numbers, sequences and series, Taylor series and differential equations, have been removed. Where gaps are evident, they are included in both the theory and examples worked in lectures, but no space has been left for the completion of exercises.

An alternative approach to the use of gaps in lecture notes occurs for the calculus subject on offer to science students. The theory component of the notes is complete, but spaces are left for the examples worked in lectures and the additional exercises that are for students to complete (Figure 3.3). Answers are only provided for selected exercises. Worked solutions are not provided.

Theory	Exercise space
6.7 Application: Radioactive Decay The half-life of a radioactive material is the time it takes for one-half of the material present to decay. In general, the equation of natural decay ($k > 0$) is given by $\boxed{p(t) = ce^{-kt}.}$ As before, with $t = 0$, we find $c = p(0)$. So, to find the half-life we solve $\frac{p(0)}{2} = p(0)e^{-kt} \quad \Longrightarrow \quad$ __________ $\Longrightarrow \quad -kt =$ __________ $=$ __________ $\Longrightarrow \quad kt =$ __________ Each element has its own value of k.	**Exercise:** Make small sketches of the following functions. $y = f(x) = x^2$ $\qquad$ $y = g(x) = e^x$ Find the following limits. $\lim_{x\to 1} f(x) =$ $\qquad$ $\lim_{x\to 2} g(x) =$

Figure 3.3 Use of Gaps in Lecture Notes for MATH151

3.2.9 Assessment of Learning

The assessment for MATH141 is a skills approach in which students are asked to complete mathematical problems that do not have discipline context and with little need to demonstrate an understanding of what the techniques are used for in their disciplines. With the time limitations in the Basic Skills Tests and the Mid-Session Test, only the quickest of strategies is useful.

After the second Basic Skills Test, the students in MATH141 proceed to new work on topics that are tested in a Mid-Session Test in week 8. This test is also based on multiple-choice questions. An example of the Mid-Session Test is included in Appendix 3. In the Final Exam, students are tested with short problems, comparable in structure to those undertaken for tutorial classes. An example of the Final Exam is included in Appendix 4. In the Final Exam and the Mid-Session Test students are allowed to take an A4 'cheat sheet' of mathematics formulae that they may need to use.

The assessment scheme used since 2002 is that marks are calculated for each student based on two separate weighting systems (Table 3.4). The final mark is the higher of the two. Starting in 2004, students who have performed well in either of the Basic Skills tests that are administered in weeks one and four of the subject receive a bonus provided that their best mark under schemes A and B is over 50%. The nature of this bonus has varied over the years. In 2007, a student whose best mark was 15 out of 20 received a bonus of 1% while a student whose best mark was 16 or more out of 20 received a bonus of 3%.

Table 3.4 Students Learning Assessment for MATH141 from 2002

	Method A	**Method B**
Assignments	10%	10%
Tutorial Quizzes	10%	10%
Mid-Session Test	20%	10%
Final Exam	60%	70%

3.2.10 UOW Transition to University Programs

In Chapter 2, a distinction was made between general programs aimed the over-all transition to university, those involved specifically with the transition to university mathematics and those providing learning support throughout the session. At the University of Wollongong, the distinctions are not so clear. A lecturer from the University of Wollongong Learning Development team was asked to clarify the nature of the help and support offered to students and indicated that they did not 'offer transition programs as such but do approach transition issues through a number of options'. These included:

1. Integrated academic literacy and learning support (can involve resources embedded into subject WebCT site, team teaching with subject lecturer etc) within core subjects especially where these subjects are taken at a transitional point in a student's course (eg 1st year UG or PG), where the subject attracts large numbers of international and/or NESB students.
2. Parallel workshops (linked to a subject but taught outside lecture time although often timetabled and promoted by the subject co-ordinator). This target the same groups as option 1 but provide an additional layer of support to option 1 and usually concentrate on language associated with assessment tasks in that subject.
3. Generic workshops covering a range of academic literacy and learning issues- usually attended by students in transition to university but open to all students.
4. Individual appointments with a language and learning advisor (James, B. 2007, pers. comm., 9 August).

Learning Development (http://www.uow.edu.au/student/services/ld/) at the University of Wollongong provides services of use to the student in transition to university but also available throughout the session. Help available includes:

- Learning Development: free help and workshops to develop academic reading, writing, study and exam skills.
- Student Services Counselling Services: offers free counselling to students and staff dealing with difficult life issues.
- Student Equity and Diversity Liason: offers assistance to students with regard to welfare, financial grants and liason with the disability program, counselling services, learning development, careers service, etc (http://www.uow.edu.au/student/services/fye/resources/index.html#1).

Learning Development also offers a PASS program as a transitional program that is available to students in MATH141. This is discussed in Section (3.2.11). Learning Development at the University of Wollongong is not a mathematics learning support centre; rather it focuses on language and literacy assistance.

At the University of Wollongong two approaches have been tried to prepare students for MATH141. These include the Bridging Mathematics subject, last taught in 2004, and the Enabling Mathematics subject, which commenced in 2005. To ascertain the nature of each of these programs and issues associated with them, four lecturers and/or coordinators were interviewed or surveyed.

3.2.10.1 Bridging Mathematics

Students attended Bridging Mathematics for three hours a day over a two-week period in the summer prior to entry to the University of Wollongong. The contact was composed of two hours of lecture and one hour of tutorial. Students had interaction with the lecturer and tutor for 30 hours in total. The emphasis on this program was review of the topics: algebra, trigonometry, co-ordinate geometry, functions and calculus. The approach taken was algorithmic with a focus on learning skills.

Bridging Mathematics was not considered to be a successful approach to preparing students for MATH141 as students still found it difficult to pass MATH141. There were individual successes, for example, for one of the ‘Lost Boys’ of Sudan (*Campus News*, University of Wollongong, vol. 10, no. 2, 2007), a refugee who came to Australia and who found that Bridging Mathematics allowed him to begin an engineering degree at the University of Wollongong. For most, however, the duration of Bridging Mathematics was considered to be too short. Further, the students did not have time between lectures and the tutorial to practice the mathematical skills.

Bridging Mathematics was abandoned in 2004 and replaced in the first session of study in 2005, by Enabling Mathematics. As a former coordinator indicated:

> The Bridging [Mathematics] subject seems to be essentially useless. A better option may be to provide self-directed learning materials … bridging was not successful and so Faculty of Engineering asked us to run the longer Enabling Mathematics subject. The three weeks in Bridging [Mathematics] subject is simply not enough to learn many new mathematical concepts … as the students were mathematically weak.

3.2.10.2 Enabling Mathematics

From 2005, students not satisfying the mathematics entry requirements for MATH141 were given provisional enrolment in an engineering degree, provided they pass Enabling Mathematics. Enabling Mathematics for Engineers (MATH010) runs during the first session at the University of Wollongong.

> The subject covers the main topics which are taught in mathematics years 11 and 12 at school ... The general topic areas are: algebra, trigonometry, coordinate geometry, functions and calculus. The focus is on developing mathematical skills and improving competence and confidence in the language and terms of mathematics (*2007 Undergraduate Handbook,* The Calendar Series, vol.1, University of Wollongong, 2006, p. 482).

Students who passed MATH010 (Enabling Mathematics) together with those who fail MATH141 in the Autumn Session, take MATH161 (Mathematics 1E Part 1) – the equivalent to MATH141 – in the Spring Session. If they pass the MATH141 equivalent subject, they take MATH162 (Mathematics 1E Part 2), which is equivalent to MATH142, in the Summer Session.

In Enabling Mathematics, students are taught for six hours per week over thirteen weeks. Four hours are for lectures and two hours for tutorials, with a total of 78 hours interaction. One of the lecturers interviewed indicated that Enabling Mathematics was more helpful than Bridging Mathematics for mature students and lower-level ability students who had left school at year 10 or who had completed the lowest level of mathematics in year 12. In Enabling Mathematics, these students had a greater opportunity to practice topics. Both Bridging Mathematics and Enabling Mathematics have been described by staff as 'Mostly skills based'. Enabling Mathematics appeared to involve an instructivist teaching approach. This appears to contradict the statement of the subject Learning Outcomes defined in the subject handout for Enabling Mathematics for engineers MATH010 as follows:

> After successful completion of this subject, students should be able to:
> - understand and have basic knowledge of the principles and techniques required in courses given in later years in Mathematics and other disciplines;
> - develop problem-solving skills … ;
> - introduce general mathematical principles which should lead to an ability to think logically and analytically.

The textbook used was Jones and Couchman (1981). A second 'in-house' book used was, *Notes for Enabling Mathematics for Engineers, MATH010.* This contained mathematics problems that are needed for assignments and practice. Handouts previously used in the Bridging Mathematics program supplemented these resources.

Two independent non-published follow-up reports of outcomes (Porter 2007a; Sandison 2007) were accessed. The failure rates for MATH010 dropped from 17% to 10% between 2005 and 2007, as reported in Table 3.5.

Table 3.5 Failure Rates in Enabling Mathematics (MATH010)

	2005		2006		2007*	
	N	**%**	**N**	**%**	**N**	**%**
Fail MATH010	5	17.2	4	13.3	4	9.7
PC/P MATH010	11	37.9	5	16.7	11	35.5
C/D/HD MATH010	13	44.8	21	70.0	16	51.6
Totals	29	99.9	30	100.0	31	96.8

*One student still incomplete

As it was not possible to implement the change evaluation for MATH010, there are insufficient data to help understand why the proportion of students with Credits, Distinctions and High Distinctions jumped to 70% in 2006 and fell again in 2007. Conclusions drawn by Porter (2007a) on the analysis of the 2005 intake are as follows:

> Data collected October 2006 of the second year of students' study, reveal that 20 the original 29 students in MATH010 remain referred or active.
> - Of those students 20 per cent have switched to degrees outside the Engineering Faculty;
> - Seventy five per cent are listed as in Engineering but 10 per cent are not currently enrolled in subjects; and
> - Five per cent are enrolled in Science (Physics).

By midyear 2007, students from the 2006 intake should have completed the MATH141 equivalent and the MATH142 equivalent. Analysis of the outcomes by midyear 2007, examining the progress of the 29 students entering the Enabling Mathematics subject in 2005 and 30 students in 2006 are summarised in Tables 3.6 and 3.7. Of the 2005 intake only five students out of 29 students and on the 2006 intake only six students out of 30 who Enabling Mathematics had passed all three subjects (Porter 2007a).

Table 3.6 Students whose Result was Pass (or better) in MATH010 and who took MATH141 Equivalent*

MATH141 Equivalent	**2005**		**2006**	
	N=22	**%**	**N=25**	**%**
Fail	13	59.1	8	32
PC/P	8	36.4	14	56
C	1	4.5	3	12

* Two students in 2005 and one student in 2006 who passed MATH010 did not take MATH141 Equivalent

Table 3.7 Students whose Result was Pass (or better) in MATH010 and MATH141 Equivalent and who took MATH142 Equivalent*

MATH142 Equivalent	2005		2006	
	N=9	%	N=14	%
Fail	4	44.4	8	57.1
P/PC	3	33.3	5	35.7
C/D	2	22.2	1	7.1

* Three students in 2006 who passed MATH161 did not take MATH142 Equivalent

Based on these results Enabling Mathematics is successful in that:

- the failure rates were less than for other 100 level undergraduate mathematics subject where it is not unusual to have failure rates of 15-30% and
- it provides an opportunity for students to enrol in an engineering degree in which they would otherwise not be allowed to enrol.

On the other hand, Enabling Mathematics had poor success in terms of the proportion of students able to successfully complete the next mathematics subjects in the sequence. An academic staff member questioned about the comparative success of Bridging Mathematics and Enabling Mathematics concluded:

> Enabling [Mathematics] does better [than Bridging Mathematics] mainly because it is longer and so students have more time to practice and absorb the ideas. It is also made very clear to the students that they are being given a very special opportunity and that they will need to work hard. On the whole they do work well. However, the subject is still trying to cover two years of school mathematics in 13 weeks for students who have previously done poorly in mathematics. It seems about one third get through the follow up subjects. This is a very good effort when all the difficulties are considered … Given that they are weak to begin with I believe a minimum time of the course should be one year. The lack of time for complete confidence is indicated by the fact that while most of the students have learnt enough to do reasonably well at the exam these very skills seem to be completely forgotten or misunderstood just a few weeks later when they start the next subject … Enabling [Mathematics] seems to be worthwhile as it allows a significant number of students to succeed at an engineering course. Without the Enabling [Mathematics] subject these students would not be given the chance. However, the number succeeding is lower (about a third) than is desirable. It seems the best way to improve this would be to insist on a full year course or perhaps, better, a full foundation year.

Comparisons with other bridging programs are difficult to make. Boland (2006), for example, taught a semester-long bridging program to students prior to university entrance. He reported that 70% of students who chose to go to university having completed the bridging program were considered to be ‘well on the road to a degree’, and further, that three had completed honours degrees. It is not possible to compare the entry levels of the students involved. It is evident, however, that Boland’s program was quite different, involving technology which helped students explore mathematical concepts and develop skills. It was also run prior to university entrance.

The analysis of Bridging Mathematics and Enabling Mathematics was undertaken retrospectively. These were not subjects to which this researcher had access when commencing studies, but became a focus toward the end of the thesis when questions as to what else could be done to help students emerged and the literature was again reviewed.

3.2.11 Learning Support for Mathematics at the University of Wollongong

Many universities in Australia provide mathematics learning support. This may take the form of one-on-one drop-in sessions, work-space and materials. At the University of Wollongong, students in MATH141 have not had access to these types of mathematics learning development services. They have had access to two other forms of support, Opportunity Classes and the Peer Assisted Study Sessions (PASS) program.

Peer Assisted Study Sessions (PASS)

The PASS program is accessible by students in MATH141. PASS is described as follows:

> PASS is a program where students work together to consolidate understanding, reinforce key concepts and develop effective study strategies. PASS consists of weekly one-hour, non-compulsory sessions led by ‘Peer Leaders’, students who have excelled at the subject in the past. PASS is provided for all students who want to improve their understanding of course material and improve their grades
> (http://www.uow.edu.au/student/services/pass/overview/index.html).

The program is non-remedial and intended for all students, but participation is voluntary. The style of teaching heavily emphasises collaborative learning,

> *Collaborative Learning* is an instruction method where students of various performance levels work together to achieve a goal … Collaborative learning is integral to PASS. Learning theory suggests that students who collaborate with their peers and take an active approach to their learning not only earn higher grades, but also have a stronger ground up understanding of course material
> (http://www.uow.edu.au/student/services/pass/UOW021327.html).

The aims of PASS are to:

- Improve learning techniques applicable to your subject within the context of university study. The aim of this is to provide you with the skills to become an effective learner
- Improve understanding of subject content
- Be a valued member of your PASS group
- Improve your communication skills
- Have the chance to ask questions that may seem silly, in a supportive environment
- Have access to more study materials, such as past exams or mock exam questions
- MAKE MATES & HAVE FUN!
  (http://www.uow.edu.au/student/services/pass/UOW021327.html).

The teaching or rather the roles of the leader is described as follows:

- Is an experienced student, well versed in the content of their course
- Operates as a model student and relays tips on their effective study skills for your discipline
- Will assist you in working out what to learn as well as how to learn it
- Will plan and facilitate activities which aim to encourage collaborative learning
- Will model relevant critical thinking and problem solving techniques
- Will empower you to become an independent learner
  (http://www.uow.edu.au/student/services/pass/UOW021327.html).

Evaluation data for the PASS program at the University of Wollongong are listed on the webpage (http://www.uow.edu.au/student/services/pass/evaluation/) ‘Pass Program Results’. Based on 6109 students in 2003 and 2004, from Business Studies, Computing, Mathematics, Health and Health Sciences evaluations suggested that those who attended PASS sessions tend to perform better than students who do not. Furthermore, referring to Figure 3.4 there appears to be a positive association between the number of PASS sessions attended and the mark obtained.

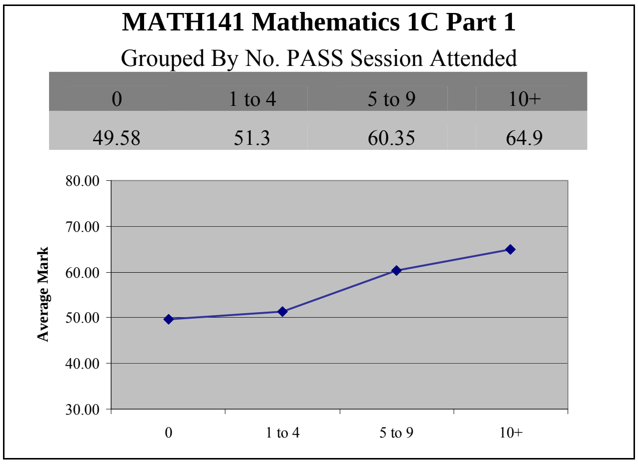


Figure 3.4 Final Percentage of Students' Mark in MATH141
Who Attended PASS Program in 2007

Opportunity Classes

Opportunity classes are available to engineering students taking MATH141, who are selected by their faculty. The main difference between opportunity classes and regular classes is that the class size for opportunity classes is a maximum of eight students, whereas the maximum class size for regular tutorials is 16 students. Opportunity students are given an assignment in each of weeks one to eleven inclusive, whereas students in regular tutorials have assignments every second week. This meant that the 10% mark for the assessment for the opportunity students was based on weekly assignments rather than fortnightly assignments for regular students.

3.2.12 Entry Level Skills

Since 1997, it has become the custom to test the entry-level mathematics skills of students, at the University of Wollongong, to see if they have the assumed knowledge and to focus on developing the deficit skills. Knowing which topics were most in need of development was also important for guiding the anticipated creation of learning resources. Data gathered over the period 2004-2005 have been used as a baseline, so that comparison may be made when innovations are introduced.

The distribution of MATH141 student marks in the first Basic Skills Test of 2004 is shown in Figure 3.5. A mark of 16 out of 20, or higher, for the Basic Skills Tests is considered to be a pass. Experience shows that students who cannot reach this level by the second skills test struggle to pass the subject because of their poor ability in performing basic mathematical manipulation and their poor grasp of fundamental concepts. Only 15% of students scored 16 or higher on the first test, indicating that 85% of the class in week 1 did not have the required command of basic mathematics skills. According to the coordinator, this is despite the fact that all students in the subject have taken Two-Unit Mathematics in high school, which is designed to equip them for further studies in mathematics as a minor discipline at tertiary level (Mathematics, previously called 2-Unit Mathematics in New South Wales). Furthermore, 24% of the intake in 2005 had passed a higher level mathematics subject in high school which is designed to equip them to take normal first year university mathematics subjects (Mathematics Extension 1, previously called 3-Unit Mathematics, in New South Wales, http://www.boardofstudies.nsw.edu.au/syllabus_hsc/syllabus2000_listm.html).

Almost half of the class (46%) scored ten or less, 24% of the students scored eight or less (Figure 3.5).

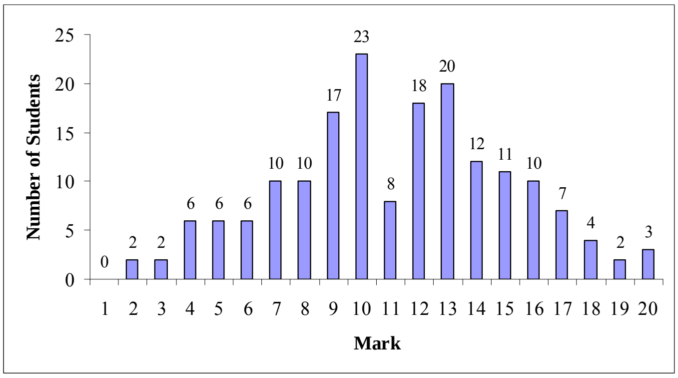


Figure 3.5 Distribution of Student Marks in Basic Skills Test 1, 2004

In the first lecture of MATH141 in week 1, students are given a Basic Skills Test composed of multiple-choice questions to assess their entry-level skills (Appendix 1). After eight hours of lectures revisiting fundamentals mathematical skills include the topics: indices, surds, logarithms, factorisations, algebraic fractions, function, quadratic equations, geometry and trigonometry, students are again tested in the fourth week of session (Appendix 2). The second Basic Skills Test is to ascertain if their basic skill set has improved. To clarify, in this thesis these two tests are referred to as Basic Skills Test 1 (BST1), carried out in week 1, and Basic Skills Test 2 (BST2), carried out in week 4. The Basic Skills Test 2 was followed by a Mid-Session Test (MST) in week 8 and a final examination after 13 weeks of study. An academic formerly lecturing in the subject believed that the purpose of the Basic Skills Tests has been more to scare students than anything else.

In 2004, 2005 and 2006 the Basic Skills Tests were different but were believed similar in standard. Video worked solutions were developed using questions from the 2005 and 2006 Basic Skills Tests and through this process the questions became available to students. The 2004 Basic Skill Tests was not available for students. In 2007, the Basic Skills Tests 1 and 2 from 2004 were re-used. This was done to compare intake skills over time. It also allowed an analysis of the impact that the innovations introduced had on students' performance. This is examined and discussed in Chapter 5. Students were not allowed to use calculators in 2007. The lecturer suggested that the calculator should have an effect on only one question. This would invalidate the comparison for question 9 'arithmetic' (including the substitution of values). Every test contained 20 questions, sometimes with a different number of questions on the topics. As can be seen from Figure 3.6 not only is the mean mark comparable in 2004 and 2007, but so is performance on each skill, except for question 9.

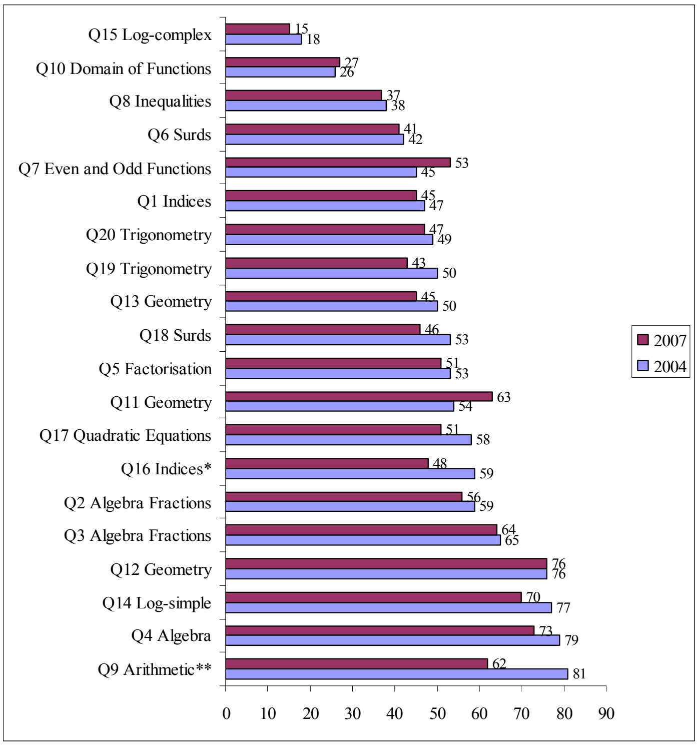


Figure 3.6 Comparison of Percentage of Correct Responses for Topics in Basic Skills Test 1 for 2004 and 2007
* $p < 0.05$, ** $p < 0.001$

A one-way ANOVA ($F_{3,\,692} = 5.23$, $p = 0.001$) demonstrated differences in the mean marks for the Basic Skills Test 1 over the four years. A Post Hoc Scheffé test revealed that the only significant difference was between the mean mark in year 2004 and that for 2006 (Table 3.8). A Levene test for homogeneity of variance revealed that variances could be considered equal ($F_{3,\,692} = 1.65$, $p = 0.176$).

Table 3.8 Baseline Skills Test Mark Week 1 Years 2004-2007

Year	N	Mean	S.D.
2004	177	11.18	3.94
2005	150	10.80	3.54
2006	175	9.66	3.49
2007	194	10.68	3.94

Given that the Basic Skills Tests in 2004 and 2007 were the same but different to those in 2005 and 2006, and given that innovations were introduced for the 2006 and 2007 cohort, a decision was made to focus on the analysis of baseline data collected in 2004 and 2007.

Questions on the Basic Skills Test 1 examined fundamental mathematical skills. Questions and outcomes are presented in Table 3.9 and a complete listing of questions and all options are provided in Appendix 1. Analysis of the Basic Skills Test 1 in 2004 and 2007, eliminating the results of question 9, revealed that students' best four skills remained consistently in the areas of:

- simplifying algebraic expression (73-79% correct),
- simple logarithms (71-77% correct),
- point of intersection (76% correct) and
- algebraic fraction (64-65% correct).

The poorest skills remained consistently in the areas of

- logarithms with multiple steps (15-18% correct),
- domain of function (26-27% correct) and
- inequalities (37-38% correct).

Table 3.9 Basic Skills Test 1 Ranking Worst to Best Answers in 2004

Number	Topics	Question	% Correct 2004 N=193	% Correct 2007 N=218
15	Logarithms	The expression $\log_a(xy^2)+\log_a(yz^2)-\log_a(xz^2)$ simplifies to	18.1	15.1
10	Domain of Function	The domain of the function $f(x)=1/\sqrt{1-x^2}$ is the set of x such that	25.9	27.1
8	Inequalities	The values of x which satisfy the inequality $\lvert 3x-4\rvert<2$ .lie on the interval	37.8	37.2
6	Surds	$\sqrt{a^2+b^2}$ is equal to	41.5	40.8
7	Even and Odd Functions	Given that $f(x)=x^2+3+1/x^2$ which of these statements is true?	45.1	53.2
1	Indices	$a^{-2}b\times ab^{-2}/a^{-4}b^3$ simplifies to	46.6	45.0
20	Trigonometry	If $\sin\theta=3/5$ and $0<\theta<\pi/2$ then $\tan\theta$ is equal to	48.7	47.2
19	Trigonometry	Given x with $0\le x\le 2\pi$ such that $\sin x=1/2$ then x is equal to	50.3	43.1
13	Geometry	Geometrically the equation $x^2+2x+y^2=0$ describes a	50.3	45.4
18	Surds	$2/(\sqrt{3}+1)$ is equal to	52.8	45.9
5	Factorisation	$(x-1)^2-(2x)^2$ equals	53.4	51.4
11	Geometry	The equation of the straight line perpendicular to $y=2x+3$ with y intercept 1 is	53.9	62.8
17	Quadratic Equations	The exact solutions to the equation $x^2-3x-2=0$ are	58.0	51.4
16*	Indices	The value of x that makes the equality $4^{x+1}=1/8$ true is	58.5	48.2
2	Algebra Fractions	$((x^2-4)/(2x-4))\times 2/(2+x)$ is equal to	59.0	56.4
3	Algebra Fractions	$3/(x-y)-2/(x+y)$ written as a single fraction is	64.8	64.2
12	Geometry	The lines $y=2x$ and $y=-3x+1$ intersect at the point	75.6	76.1
14	Logarithms	$\log_2 16$ is equal to	77.2	70.6
4	Algebra	The expression $3m(m-1)-2(m^2+2m+5)$ can be written more simply as	78.8	73.0
9**	Arithmetic	Let $s=ut+(1/2)at^2$, where $u=5$, $a=6$ and $t=2.4$ then the value of s is	81.3	62.4

* $p < 0.05$, ** $p < 0.001$

Only three of the topics or questions posed had a correct response from 75% or more of the students.

A test for the differences in proportions revealed that apart from question 9, ‘arithmetic’, where the comparison was invalid because one cohort had an advantage in using a calculator, there was only one question, question 16, ‘indices’, where there was a significant difference in the proportions correctly answered ($Z = 2.11$, $p < 0.05$). In 2004, 59% of students correctly answered this compared to 48% in 2007.

In Section 3.2.14, *Analysing Mistakes,* students’ answers to these questions are further analysed in order to determine whether there are common reasons for mistakes, so that materials may be produced to develop students’ mathematical learning.

3.2.13 The Nature of Mistakes

> Any idea or problem or body of knowledge can be presented in a form simple enough so that any particular learner can understand it in a recognizable form … Many subjects, such as mathematics, have alternatives modes of representation (Bruner 1966, p. 44 & 45).

Deep analysis of student errors often involves examination of students’ written work and discussion, in which students explain their errors. This was not possible for this study. However, an analysis of the options or wrong answers selected can potentially identify the type of mistakes that students make.

An analysis of the literature reveals classifications of common mistakes and this was used to analyse the mistakes made by students in the Basic Skills Test 1. The description of common mistakes involves three broad categories *arbitrary errors, executive errors*, and *structural errors.*

Arbitrary Errors

Arbitrary errors are those where the students ‘ignore a part of available information, while acting on the rest’ (Donaldson 1963, p. 201) and when ‘the subject behaved arbitrarily and failed to take account of the constraints laid down in what was given’ (Orton 1983b, p. 4).

Executive Errors

Executive errors refer to those involving a 'failure to carry out manipulations, though the principles involved may have been understood' (Orton 1983b, p. 4). In solving an equation such as $2x^2 - 8x = 0$, an error happens when students lose $x = 0$ by cancelling or dividing equation by x, which is a structural error. If students incorrectly factorise the equation into $2x(x-8) = 0$, the error is executive.

Structural Errors

Structural errors are those which arise from a false expectation about the structure of the problem and a fundamental failure to understand the relationships concerned in the problem or to grasp some essential rule to solution (Donaldson 1963). Structural errors happen when there is a lack of understanding of topics (Orton 1983a). For example, in the expansion of $3(a+b)^2$ if students lose the middle term, $6ab$, this is because of lack of understanding of quadratic expansion and so the error is structural.

Hirst (2002) referred to procedural extrapolation, equation balancing, and pseudolinearity errors, which can be due to *structural errors*.

Overgeneralisation Errors

What Hirst called procedural extrapolation can also be referred to as *overgeneralisation* (Fischbein & Barash 1993). For example, to solve $(x-a)(x-b) = 0$, students are taught that each of the bracketed expression should be set equal to zero and solved. That is $(x-a) = 0$ or $(x-b) = 0$. When students are asked to solve $(x-a)(x-b) = k$ they sometimes overgeneralise and instead of setting $(x-a) = k$ and $(x-b) = k$ they do the same for $(x-a)(x-b) = 0$ without considering that left hand side equals k not zero. Another example is to differentiate $f(x) = e^{x^2}$ an erroneous extrapolation is $f^{'}(x) = e^{x^2}$, and $f^{''}(x) = e^{x^2}$. This is when students think the derivative of the exponential function is the exponential function, whatever the exponent.

A special case of overgeneralisation called *equation balancing* was identifies by Pimm (1987). Often students in elementary algebra are told the principle that if they do the same manipulation or operation 'to both sides' of an equation they are still equal. Hirst

(2002) noted that students change the expression from 'to both sides' to '*on* both sides'. For example, given $a+b=c+d$ and ask to solve for c students are taught that to subtract d from *both sides* of the equation. When students are asked to evaluate $\int \frac{1}{x^2}dx$ they used $\int \frac{1}{x}dx = \ln|x| + c$ and mistakenly square *on both sides* and get $\ln|x^2| + c$.

Linearity Errors

Fischbein and Barash (1993) referred to linearity errors, and Hirst (2002) referred to *pseudolinearity* such as $\sqrt{a+b} = \sqrt{a} + \sqrt{b}$ and $(a+b)^2 = a^2 + b^2$, $\log(x+t)$ as $\log x + \log t$. These were interpreted as evolving from the *extrapolation of the distributive law* of multiplication over addition (Fischbein & Barash 1993).

Inequality Signs

When students solve rational inequalities, they multiply or divide both sides of an inequality by a negative number without changing the direction of the inequality sign (Tsamir & Almog 2001).

Different Form

The form $3+x=8$ is easier for students to deal with than $x+3=8$ (Suppes 1966, cited in Bruner 1966, p. 55). The interpretation for this was the potential interference between linguistic habits from ordinary English and mathematical habits.

Memorising Equations in a Particular Notation

Sazhin (1998) referred to notations as one problem with algebraic equations. For example, if the distance in one lecture introduced as 's', it should remain so until the end of the course. Sazhin (1998) attempted '… to persuade students to understand the structure of the equations rather than to memorize the notation (adopt deep rather than surface learning) but I had little success with most of the group' (p. 147).

Checking and Monitoring

Cipra (1983) referred to faulty methods of *Checking and Monitoring.* One way to remedy 'stupid mistakes' is when '… you know you tend to get this wrong, ask yourself, Did I get it right this time?' (Cipra 1983, p. 59).

Other Common Errors

'1) Missing minus signs; 2) disappearing parentheses; 3) lost coefficients; 4) dropped or otherwise damaged exponents; 5) fractional inversion … ; 6) uncontrollable computations' (Cipra 1983, p. 60).

From my experiences, mistakes sometimes happen when students substitute the wrong value for a variable. Another error happens when students take a variable or a number to the right or left hand side without changing its sign. This means splitting the denominators as they used to do for numerators such as $\frac{x+1}{x^2+5}=\frac{x+1}{x^2}+\frac{x+1}{5}$ (wrong) and $\frac{x+1}{x^2+5}=\frac{x}{x^2+5}+\frac{1}{x^2+5}$ (right).

3.2.14 Analysing Mistakes

Often diagnostic tests are constructed so as to elicit standard misconceptions (Gill 1998), alternative conceptions (Treagust 2006), or to identify students' mistakes and provide suitable feedback and explanation to their answers (Kung et al. 2002). The complexity of questions in terms of the number of steps involved can also be analysed (Lee & Robinson 2005). For MATH141, the options were not selected to elicit common or conceptual mistakes. The lecturer indicated that 'Most of the questions come from sets of questions that other people have devised. Any questions that I wrote were based on similar questions, including the mistakes' (Nelson, M. I. 2007, pers. comm., 20 June). For this reason, it was difficult to interpret the students' choice of options in the multiple choice questions without being able to analyse the working of the student so as to better understanding their thinking. An initial analysis of the errors made by students was frustrating in that it often appeared that no plausible interpretation could be found for students selecting particular options. By using the categories of errors that are commonly identified in the literature as a template, it became possible to distinguish errors as those reflecting common errors from those that remained implausible options. More systematic setting of the options to trap likely errors could improve the tests and make them better learning tools for follow-up debriefing of students.

A sample of six questions chosen from the Basic Skills Test 1 in 2004 and 2007 is used to illustrate the types of errors students make. Five questions were selected to illustrate the nature of student reasoning errors based on the chosen options, where these errors appeared plausible. One question was chosen to illustrate where identifying the nature of the errors was not possible because the option was not plausible. All six questions were examined over all error categories. The notation √ is placed against a particular category of mistake in Table 3.10 if it had been elicited by students’ choices of options. Only categories of errors identified in the options of these six questions are presented in the table. There is some overlap as for example; structural errors may encompass several errors that have been individually labelled say, linearity errors or pseudolinearity. Given that each question had five options, it is possible that the students’ selection of answers could reflect several types of errors. In some questions there may be an error that dominates, that is, most students select a particular incorrect option. As mentioned previously questions and percentages of correct responding to each option are presented in Table 3.9 and a complete list of questions and options are provided in Appendix 1.

Table 3.10 Template and Analysis of Errors for Selected Questions

Type of error	Q6	Q9	Q10	Q15	Q17	Q18
Structural error	√		√	√	√	√
Arbitrary error		√	√			
Executive error		√	√	√	√	
Linearity errors or pseudolinearity	√		√	√		
Incorrect direction of the inequality sign			√			
Checking/Monitoring	√	√	√	√	√	√
Disappearing parentheses					√	
Dropped or otherwise damaged exponents		√	√			
Substitution		√			√	

The questions chosen have been described according to the dominant plausible error elicited by the options or, in the first case, according to the implausibility of options.

3.2.14.1 Implausible Options

Question 18 was one of the questions where at least some of the options were implausible. The choice of some of the options could suggest that students did not *check* their working appropriately. It asked students to simplify the expression $2/(\sqrt{3}+1)$. Only 53% of students answered this question correctly in 2004 (Table 3.11).

Table 3.11 Student Answers to Question 18 in 2004 and 2007

Question 18	Options	2004		2007	
		N=193	**%**	**N=218**	**%**
$2/(\sqrt{3}+1)$ is equal to	a) $\sqrt{3+1}$	9	4.7	7	3.2
	b) $\sqrt{3}-1$	**102**	**52.8**	**100**	**45.9**
	c) $\sqrt{3}$	10	5.2	16	7.3
	d) 2	6	3.1	15	6.9
	e) $(\sqrt{3}-1)/2$	59	30.6	77	35.3
	No answer	7	3.6	3	1.4

To simplify the expression, that is to eliminate the surd on the denominator, the numerator and denominator must be multiplied by the conjugate, $\sqrt{3}-1$. That is $\frac{2}{\sqrt{3}+1}\times\frac{\sqrt{3}-1}{\sqrt{3}-1}=\frac{2(\sqrt{3}-1)}{3-1}=\sqrt{3}-1$. It is possible that students do not have sufficient information, namely an understanding of the conjugate and this therefore can be classified as a *structural error*.

Clearly a common mistake has been made for this question with approximately 30% of students responding (e). However, it is extremely difficult to be certain as to how the mistakes for any of the incorrect options were made. Several attempts have been made to try to recreate how the mistakes could have been made. Perhaps

- as a first step, students ignore 2 from the numerator in $2/(\sqrt{3}+1)$ and consider $1/(\sqrt{3}+1)$. Then $\frac{1}{\sqrt{3}+1}\times\frac{\sqrt{3}-1}{\sqrt{3}-1}=\frac{\sqrt{3}-1}{3-1}=\frac{\sqrt{3}-1}{2}$, this may reasonably be assumed to be an *arbitrary error* in which students ignore some information and perhaps do not *check* their worked solutions and
- alternatively, to arrive at the same incorrect answer students after correctly multiplying the numerator and the denominator by the conjugate, $\sqrt{3}-1$, at the second stage ignore 2 from the top. This would be considered to be an *executive* error when the student fails to carry out the manipulations although

the principle of multiplying by the conjugate was understood. It also suggests the failure of *checking* processes.

But the choice of options (a), (c) or (d) appear implausible so student reasoning cannot be interpreted. To better construct the options for this question it would be useful to observe students while incorrectly completing a question to identify the most common mistakes. This is quite visible to tutors when teaching in whiteboard tutorials room such as in MATH141 where each student writes their solution on the whiteboard as they solve them.

3.2.14.2 Dropped Exponents

Question 9 'arithmetic' with substitution (Table 3.12) was the question that most students answered correctly. However, even though students were allowed to take a calculator into the Basic Skills Test 1 in 2004, 19% of students failed to answer it correctly. Eighty-one per cent of students answered this question correctly in 2004 while in 2007, only 62% of the students answered this question correctly when they were not allowed to use calculators.

Table 3.12 Student Answers to Question 9 in 2004 and 2007

Question 9	**Options**	**2004**		**2007**	
		N=193	**%**	**N=218**	**%**
Let $s = ut + (1/2)at^2$,	a) 19.2	17	8.8	27	12.4
where $u = 5$, $a = 6$	**b)** 29.28	**157**	**81.3**	**136**	**62.4**
and $t = 2.4$	c) 29	7	3.6	26	11.9
then the value of s	d) 31.68	10	5.2	26	11.9
is	e) 0	0	0.0	2	0.9
	No answer	2	1.0	1	0.5

The most popular wrong answer is the correct answer for the formula $s = ut + (1/2)at$, suggesting that students did not take note of the squared term. This would be considered an *arbitrary error* and, more specifically, the *mistake of dropping an exponent*. The second most popular wrong answer corresponds to a *substitution error* with 6 substituted for the value of u rather than the correct value 5. This would be considered an *executive error*. There appears to be no plausible explanation for students selecting the options (c), (d) and (e). The answer 29 could possibly be a rounding error, but it is difficult to determine how the student could make this response. The number of wrong answers suggests that students did not *check* their calculations or they repeated their mistake.

Knowing that the dropping of an exponent is the most common of errors, it is possible when creating learning resources to emphasise the need to take note of the exponent in the calculation.

3.2.14.3 Linearity Errors or Pseudolinearity

Analysis revealed that students have very poor skills at basic algebraic manipulations. Students did not perform well on Question 6 (Table 3.13). In 2004 and 2007, 41-42% of students answered this question correctly.

Table 3.13 Student Answers to Question 6 in 2004 and 2007

Question 6	Options	2004		2007	
		N=193	%	N=218	%
$\sqrt{a^2+b^2}$ is equal to	a) $a+b$	96	49.7	116	53.2
	b) $\sqrt{a+b}$	10	5.2	4	1.8
	c) $a-b$	4	2.1	2	0.9
	d) None of the above	**80**	**41.5**	**89**	**40.8**
	e) a^2+b^2	2	1.0	5	2.3
	No answer	1	0.5	2	0.9

Nearly half of the students chose $a+b$ as their answer to solving $\sqrt{a^2+b^2}$. Mistakes similar to this happen when students:

- have a lack of understanding of the surds topic, *structural error*,
- use extrapolations of the distributive law in the erroneous use of *linearity*,
- fail to check by correctly squaring the various options provided. For example, for option (a) squaring $a+b$ gives $a^2+2ab+b^2$ not the required expression $\sqrt{a^2+b^2}$ and

- mistakenly consider $\sqrt{a^2+b^2}$ as $\sqrt{(a+b)^2}$ and hence choose the incorrect option $a+b$.

A second example of *linearity errors* or *pseudolinearity* is question 15 (Table 3.14). Only between 15-18% of students in both 2004 and 2007, could simplify $\log_a(xy^2)+\log_a(yz^2)-\log_a(xz^2)$.

Table 3.14 Student Answers to Question 15 in 2004 and 2007

Question 15	Options	2004		2007	
		N=193	%	N=218	%
The expression	a) $\log_a(xy^2+yz^2-xz^2)$	39	20.2	56	25.7
$\log_a(xy^2)+\log_a(yz^2)-\log_a(xz^2)$	b) $\log_a(xy^2+yz^2)/\log_a(xz^2)$	37	19.2	42	19.3
simplifies to	c) $\log_a\left((xy^2+yz^2)/xz^2\right)$	57	29.5	72	33.0
	d) 1	12	6.2	12	5.5
	e) $3\log_a y$	**35**	**18.1**	**33**	**15.1**
	No answer	13	6.7	3	1.4

To solve this expression the rules used are:

1. $\log(a/b)=\log a-\log b$
2. $\log(ab)=\log a+\log b$ or rearranging $\log a+\log b=\log(ab)$.

Expanding before simplifying would lead to the solution:

$$\begin{aligned}\log_a(xy^2)+\log_a(yz^2)-\log_a(xz^2) &= \log_a x+\log_a y^2+\log_a y+\log_a z^2-(\log_a x+\log_a z^2)\\ &= \log_a y^2+\log_a y\\ &= 2\log_a y+\log_a y\\ &= 3\log_a y\end{aligned}$$

Twenty per cent of students mistakenly selected the first option, suggesting that students

- had a lack of understanding of logarithms functions and rules, that is, they committed a *structural error* when mistakenly expanding the logarithm function and

- should note that $\log(a+b)$ does not equal $\log a + \log b$ otherwise they commit a *linearity error*.

Nineteen per cent students chose option (b). This suggests that these students failed to carry out the essential logarithm rules in working the solution, that is, they committed an *executive error* and failed to *check*. Nearly one-third of students who chose option (c) did not grasp essential log rules (*structural error)*.

3.2.14.4 Difficulty with Excluded Values

In responding to question 10 in 2004 and 2007, only 26-27% of students were able to find the domain of function correctly (Table 3.15).

Table 3.15 Student Answers to Question 10 in 2004 and 2007

Question 10	**Options**	**2004**		**2007**	
		N=193	**%**	**N=218**	**%**
The domain of the	a) $\lvert x\rvert \le 1$	26	13.5	27	12.4
function	b) $x \ne 1$	69	35.8	79	36.2
$f(x) = 1/\sqrt{1-x^2}$ is	c) $\lvert x\rvert \ge 1$	26	13.5	29	13.3
the set of x such that	d) x is all real numbers	15	7.8	20	9.2
	e) $\lvert x\rvert < 1$	**50**	**25.9**	**59**	**27.1**
	No answer	7	3.6	4	1.8

The following two mathematics results are important when completing this question:

- denominators in rational expression should be non-zero and
- values under the square roots should be non-negative.

Analysis of the options in Table 3.15 reveals that the most common mistakes, 36%, involved students ignoring the square root for the function. It suggests that students had:

- a lack of knowledge regarding the domain of function (*structural error*) and
- ignored the square root and the exponent of x, so they committed a *linearity error* and a *dropped exponent's error*.

The second type of mistakes, with 12-14% of students choosing option (a) and (c) involved:

- ignoring that the denominator in a rational expression should be non-zero *(structural error)*,
- failing to remember to apply what they know (*executive error)*,
- not *checking* the worked solutions and
- using the *same direction of inequality sign* when dividing both sides by (-1) as: $1-x^2 \geq 0 \Rightarrow -x^2 \geq -1 \Rightarrow x^2 \geq 1 \Rightarrow |x| \geq 1$, and they chose option (c).

Between 8-9% of students answered 'x is all real numbers', which shows these students had a lack of knowledge and understanding of finding domain of a function. All these errors may be referred to as *structural errors*.

3.2.14.5 Substitution, Checking and Monitoring

Another example showing poor numerical and algebraic skills is question 17 (Table 3.16) where students were asked to solve the quadratic equation $x^2-3x-2=0$. In 2004 and 2007, between 51-58% of students were able to successfully find the roots.

Table 3.16 Student Answers to Question 17 in 2004 and 2007

Question 17	**Options**	**2004**		**2007**	
		N=193	**%**	**N=218**	**%**
The exact solutions to the equation $x^2-3x-2=0$ are	a) $x=3/2+\sqrt{17}$ or $x=3/2-\sqrt{17}$	9	4.7	19	8.7
	b) $x=(3+\sqrt{17})/2$ or $x=(3-\sqrt{17})/2$	**112**	**58.0**	**112**	**51.4**
	c) $x=1$ or 2	26	13.5	39	17.9
	d) $x=3/2$ or $x=-3/2$	14	7.3	22	10.1
	e) no values of x exist	27	14.0	22	10.1
	No answer	5	2.6	4	1.8

To solve this question one of two approaches can be used:

- what two numbers added together give –3 and multiplied together give –2 but this cannot be worked out easily, hence the use of the equation and

- for an equation of the form $ax^2 + bx + c = 0$ the solution is given by

$$
\begin{aligned}
x &= \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \\
&= \frac{-(-3) \pm \sqrt{(-3)^2 - (4 \times 1 \times (-2))}}{2 \times 1} \\
&= \frac{(3 \pm \sqrt{9+8})}{2} \\
&= \frac{(3 \pm \sqrt{17})}{2}
\end{aligned}
$$

Between 14-18% students had a lack of algebraic skills that led them to factorise the equation as $(x-1)(x-2)$ (*executive error*). It was seen that 10-14% of students stated that this equation had no roots. It seems these students may have:

- failed to remember essential quadratic formulae (*structural error*),
- found a negative value for $\sqrt{b^2 - 4ac}$ (*executive error*) or
- tried to factorise the quadratic, and having failed to do so, concluded that it did not have any roots (*executive error*).

Five to nine per cent of students chose option (a) in 2004 and 2007. Maybe the reason why students got the question wrong is that although they use the quadratic formulae, in the end they fail to consider the numerator as one term. To remedy this error it advised that students consider using *parentheses* for the numerator. Option (d) was chosen by 7-10% of students in 2004 and 2007. Assuming that the students were able to correctly *remember* the quadratic formula, they could not correctly *use* it in order to do the substitution. This question needed to be *checked* step by step to prevent any mistakes.

The analysis of selected questions in 2004 and 2007 revealed that *structural errors* and *executive errors* are the most common kinds of error that students commit while mistakenly solving a mathematics question. There is perhaps too little time to check answers in the tests as students failed to do this on many questions. Despite the time constraint, it is probably still warranted that in the learning resources developed, students be shown strategies for checking their work.

3.2.15 Predicting Final Outcomes

It has been considered that Basic Skills Test 1, Basic Skills Test 2 or the best score of both could predict students' final grade. For 2004 MATH141 data a scatterplot of final mark and best mark of BST1 and BST2 (Figure 3.7) revealed an essentially linear relationship between final mark and best score after excluding students with the zero best score.

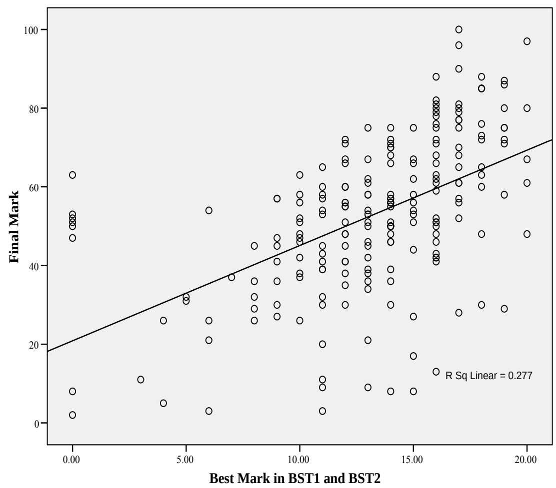


Figure 3.7 Scatterplot of Final Mark and Best Mark of BST1 and BST2

The 13 students who had missed both BST1 and BST2 were given a mark of zero for both tests and for the best score. Subsequent analysis revealed that 54% of student (n = 7) with zero as best score failed the subject with a mark of 44 or less. The remaining 46% students (n = 6) scored final marks ranging from 47 to 63, the proportion passing substantially higher than for those with best marks between 3 and 12.

This was examined using a step-wise multiple regression analysis to predict final marks after eliminating cases with a zero mark for the best mark. The predicted variables included BST1, BST2 and the best mark out of BST1 and BST2 and the interaction terms formed by BST1*BST2 mark and BST1* best mark. This was followed by simple regression using the only significant variable, best mark (Table 3.17). The best model ($F_{1,\,200}$ = 105.43, $p < 0.001$) including only the predictor best mark was given by:

$$\text{Expected (Final mark)} = 8.04 + 3.30*(\text{best mark of BST1 and BST2})$$

Based on this model, anyone with the best mark of 11 or less would be predicted to fail the subject, that is, to achieve a final mark for the subject of 44 or less. The proportion of variation, 0.345, in the final mark explained was not high.

Table 3.17 Regression Output

Model Summary

Model	R	R Square	Adjusted R Square
1	0.59 [a]	0.35	0.34

a Predictors: (Constant), Best Mark in BST1 and BST2

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26891.50	1	26891.50	105.43	0.000 [a]
	Residual	51011.15	200	255.06		
	Total	77902.65	201			

a Predictors: (Constant), Best Mark in BST1 and BST2
b Dependent Variable: Final Mark

Coefficients [a]

		Unstandardised Coefficients		Standardised Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	8.04	4.53		1.77	0.078
	Best Mark in BST1 and BST2	3.30	0.32	0.59	10.27	0.000

a Dependent Variable: Final Mark

A follow-up analysis checked the assumptions pertaining to the multiple regression analysis. These assumptions include normal distribution of errors, homogeneity of variance and linearity of the relationship.

Normality of the Distribution of Errors

The distribution of errors appears reasonably normal based on the normal P-P plot of standardised residuals (Figure 3.8).

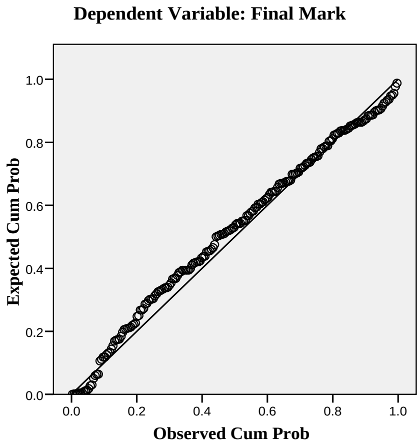


Figure 3.8 Normal P-P Plot of Regression Standardised Residual

The homogeneity of variance and linearity assumptions may be checked using a scatterplot of standardised residuals against standardised predicted scores (Kinnear & Gray 2008). As can be seen from Figure 3.9 the essentially rectangular pattern suggests that these assumptions are tenable.

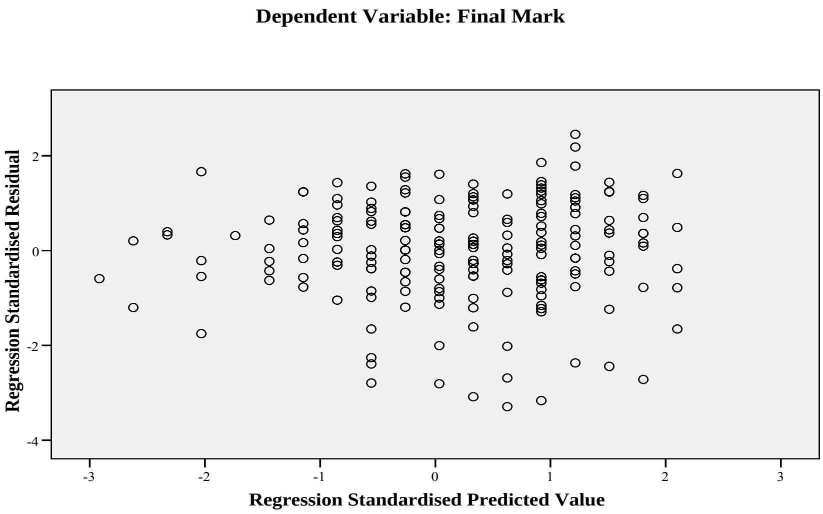


Figure 3.9 Scatterplot of Standardised Residuals against Standardised Predicted Scores

The Basic Skill Test marks rather than the best mark of the two Basic Skills Tests may also be used to predict final mark. These do not appear in the model as the best mark is highly correlated with BST1 ($r = 0.76$, $n = 177$, $p < 0.001$) and BST2 ($r = 0.95$, $n = 170$, $p < 0.001$).

3.3 Conclusion

In the context of this thesis the decline in students studying mathematics at school has led to students entering university who are ill-equipped to handle the mathematics required in their courses. This is confirmed by a skills test of students in the first week of an introductory mathematics subject (MATH141) at the University of Wollongong. The tests examined fundamental mathematical concepts that are taught at high school. Analysis of the test data reveals a group of students having very weak mathematical skills (Table 3.9). Results of student grades from 2000 and 2005 have shown that failure rate in this subject is high (Table 3.1). The aim of initial investigations was to identify the mathematical skills that students lack and the development of video resources to support students' learning.

Several findings reported in this chapter led to a decision to create new learning resources. These were:

- the relationship between final marks and performance in the Basic Skills Tests,
- identification of topics where students had greatest difficulty,
- evaluations suggesting that students wanted additional learning resources and
- the lecturer concluding that students needed additional resources.

It was thought that if the basic skills (Table 3.8 & Table 6.2) of students were improved early in the session, they would have a better chance of being able to successfully complete MATH141. For this reason, it was decided to create additional learning resources to help students make a smooth transition from high school to university mathematics. That is, it was thought that if they caught up on their basic skills, they would be able to successfully learn the new topics. This hypothesis was reconsidered after subsequent data collection.

In the next chapter, a model for evaluating innovations is discussed before documenting the design of the video learning resources and the processes for production of the resources.

Chapter 4

Design of Video Resources

> *As educators, we must prepare our students and ourselves for new and exciting forms of technology that take the best of what we have to offer as teachers and apply it to our subject matter (Diem 1997, p. 109).*

4.1 Introduction

In their descriptions of instructional design researchers (Dick & Carey 1996; Smith & Ragan 1998) concluded that all explanation consists of the core fundamentals of four stages of evaluation: analysis, design, development, implementation and evaluation to certify ‘congruence among goals, strategies, and evaluation and the effectiveness of the resulting instruction’ (Gustafson & Branch 2002, p. 18).

Gustafson and Branch (2002) defined ‘instructional design’ as a

> system of procedures for developing education and training programs in a consistent and reliable fashion. Instructional design is a complex process that is creative, active, and iterative (p. 17).

When innovation is introduced into the classroom it is important that the innovation be evaluated. This involves identification of:

- models suitable for evaluating the learning resources developed and
- techniques for the collection of data.

Rather than simply evaluating the outcomes once an innovation is implemented in the classroom, current approaches involve the evaluation of all stages of the process – from the decision to innovate and the identification of associated design issues through to the development of the project, its implementation and institutionalisation. Part of that evaluation process involves determining the needs that give rise to the innovation being developed. In the present context, this has been partly addressed in Chapter 3 through an examination of the skills of incoming students. In the context of developing video learning resources, there is also literature to consult, detailing what other researchers have found. The remaining sections in this chapter examine:

- models for evaluation of resources and techniques for the collection of evidence to facilitate that evaluation,
- identification of technologies considered but dismissed as being unsuitable for the development of the resources,
- design specifications and decisions in selecting what is to be made,
- the nature of the video production process and
- website design.

4.2 Models for Evaluation

'Technology doesn't inherently improve learning; it merely makes possible more effective pedagogy' (Beatty 2004, p. 8). Hence there is a need for an evaluation of educational innovations in order to assess whether they do this or not. To do this it is necessary to establish or adopt a framework for evaluation.

In addressing the question 'What is evaluation?', Moore (2007) wrote:

> The term evaluation is used in educational literature in different ways. It is often thought of as a systemic process. For example, it is common to evaluate the effectiveness of a system or outcomes of a project – usually at the end. This form of evaluation has limited benefits for the formative development of an improved project or system … (p. 1).

Guba and Lincoln (1981) defined evaluation as ‘a process for describing an evaluand and judging its merit and worth’ (p. 35). Stern (1990) defined evaluation as

> Evaluation is any activity that throughout the planning and delivery of innovative programmes enables those involved to learn and make judgements about the starting assumptions, implementation processes and outcomes of the innovation concerned (cited in Jackson 1998, p. 22).

One distinction made in the literature is between formative and summative evaluation. In the context of curriculum development, Scriven (1967) distinguished between these as follows:

> *Formative evaluation* produces information that is fed back during the development of a curriculum to help improve it. It serves the needs of developers. *Summative* evaluation is done after the curriculum is finished. It provides information about the effectiveness of the curriculum to school decision makers who are considering adopting it in their schools (cited in Wesis 1998, p. 31).

Scriven (1991) distinguished between evaluations using a definition attributed to Bob Stake ‘When the cook tastes the soup, that’s formative evaluation; when the guest tastes it, that’s summative evaluation’ (p. 169).

Summative evaluation has dominated the evaluation literature to the extent that formative assessment has been in a ‘struggle for its status and development’ (Fairbrother 1995). However, in the context of developing innovations or curriculum, summative assessment is often criticised because it occurs at the end of the process, when it is too late and possibly too costly to make changes. Formative assessment is therefore considered essential in the design and development of innovations. Flagg (1990) defined formative evaluation of materials as ‘the systematic collection of information for the purpose of informing decisions to design and improve the product’ (pp. 1-2) and Reeves (1993) stated ‘Formative evaluation is the essential “lifeblood” of the instructional development process’ (p. 15.11).

Guba and Lincoln (1981) described a *responsive* model of evaluation in which groups having a stake in the evaluation are identified. For example, in this study, the stakeholders are students, lecturers and developers. The needs and issues of stakeholders must be identified. Then data collection methods typically involve qualitative techniques and sometimes quantitative techniques to generate data that are *descriptive*, *judgmental* and *interpretable*. The steps in the latter stages of the process are in part determined by what has emerged in earlier stages, although sometimes conventional pre-post designs may be used.

> Responsive evaluation does not undertake to answer questions of merely theoretical interest; rather, it takes its cues from those matters that local audiences find interesting or relevant (Guba & Lincoln 1981, p. 38).

Different researchers have drawn attention to the limitations of evaluation only at the end of a project and have sought to evaluate through the several stages of implementing changes in the classroom. The responsive model can be applicable at each stage or even be seen to incorporate all other models of evaluation. In the context of this study it was useful to consider the evaluation at a number of stages. There are similarities between models that specify typically four stages of evaluation. For example:

> *Reaction, Learning, Performance and Organisation*
> The Bastiaens, Boon and Martens (2004) framework was developed for the evaluation of integrated e-learning. Within each of these levels they discussed: *goals*, including purpose, object, and criteria for the evaluation; *design*, including validity, instruments, indicators for the criteria, and technique; and *arrangement* of subjects, evaluator, costs and data collection methods.
>
> *Formative, Summative, Illuminative and Integrative*
> Davidson and Goldfinch (1998) framed their evaluation in terms of methods: *formative* to improve design, *summative* to make choices after the innovation is developed, *illuminative* to uncover unexpected important issues, and *integrative*, making the best use of the innovation.

Alexander and Hedberg (1994) identify the stages as: *Design, Development, Implementation* and *Institutionalisation*. They emphasised the need for evaluation of every major phase of an educational process (Bain 1993). These closely mirror the stages of development of most mathematics learning resources and, as such, provide a suitable framework for this study. These authors emphasised that in enhancing learning outcomes, developers first need to gather relevant data in regard to need and suitability. For this study, the data sources used to provide evidence to guide the different stages of the evaluation model are presented in Table 4.1. The emphasis in the design phase was to establish the need for video resources in specific mathematics topics. In the development phase emphasis was placed on evaluating the technology for the development of the resources, the adequacy of the resources in terms of quality and usability, and establishing that the resources would be likely to have an impact on learning outcomes. The implementation phase focused on identifying how the resources influenced learning outcomes. In the final phase, institutionalisation, the focus was on identifying whether or not the video resources and development processes had been adopted elsewhere within the institution.

Table 4.1 Evaluation Model for Video Resources

Stage	**Elaboration and Evaluation of Stages of Video Development**
Design	Establishment of need • Basic Skills Tests 2004 • Change evaluation conducted with MATH141students in 2005 • Analysis Basic Skills Tests and Mid-Session Test in 2005 to find out topics which students experience more difficulty • Literature review to find if delivery of video solutions is a most appropriate way of dealing with students' difficulties and enhance learning • Teacher experiences
Development Trial set of transition video resources weeks 1-4	Formative and Summative Evaluation of Trial Resources 2006 • Trials of technologies • Developer's evaluation of two production processes • Student trials of two types of videos in Autumn 2006 • Gathering data from interviews • Summative evaluation of production processes • Changes Basic Skills Test 1 to Basic Skills Test 2 and Mid-Session Test • Comparison of users and non-users of video resources • Student grades in 2006 • Change evaluation 2006
Implementation Full set of video resources weeks 1-12	Summative and Formative Evaluation Autumn 2007 • Student Grades in 2007 • Comparison of the outcomes in 2004 and 2007 of the same Basic Skills Test in week1 and week 4 • Comparison of students grades in 2004 and 2007 • Change evaluation 2007 • Next Step interview with lecturer
Institutionalisation	Uptake of video resources production methods Adoption of resources by university • Application for Developing Mathematics Video Resources for Science Students • Summertime Maths • Requested application for developing university-wide video resources for Mathematics and Statistics

The phases of development are actually more circular than linear. While the investigations began with assessing needs in order to design the learning resources and proceeded to development, the development phase also involved implementation with a subsequent phase of redesign, based on formative and summative evaluation. Then further development followed and a further implementation stage. As this cycle has continued it has been possible to assess how the resources and development processes have been adopted, or institutionalised.

4.3 Evaluation Techniques

A major classification of how one conducts research has two classes: quantitative research and qualitative research. Creswell (2003) defined these:

> A *quantitative* approach is one in which the investigator primarily uses postpositivist claims for developing knowledge (i.e., cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories), employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data. Alternatively, a *qualitative* approach is one in which the inquirer often makes knowledge claims based primarily on constructivist perspectives (i.e., the multiple meanings of individual experiences, meanings socially and historically constructed, with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e., political, issue-oriented, collaborative, or change oriented) or both. It also uses strategies of inquiry such as narratives, phenomenologies, ethnographies, grounded theory studies, or case studies. The researcher collects open-ended, emerging data with the primary intent of developing themes from the data (p. 18).

Within the quantitative paradigm there are different approaches. Experimental and quasi-experimental designs can be considered as two approaches within the quantitative paradigm:

> - *Experiments* include true experiments, with the random assignments of subjects to treatment conditions, as well as quasi-experiments that use nonrandomized designs (Keppel, 1991). Included within quasi-experiments are single-subjects designs.
> - *Survey*s include cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection, with the intent of generalizing from a sample to a population (Babbie, 1990) (cited in Creswell 2003, p. 14).

A second classification could be *experimental* versus *observational* studies. While the experimental studies involve a variety of designs, they include random assignment of subjects to the treatment group. Observational studies do not involve the random allocation of subjects. Surveys fall into the category of observational research. Ideally, one would implement a designed study, with appropriate controls, so that it is reasonable to attribute the outcomes to the intervention, or experimental treatment. In observational studies, associations between variables can be identified but the nature of the evidence is inadequate to attribute causality. For example, in this study the aim is to examine the impact of video learning resources on a variety of outcomes such as understanding, confidence and motivation. A simple design for an experiment with appropriate controls would be to take one cohort of students, say students from 2007, randomly assign half those students to one or two control groups (for example, no video resources, or perhaps other resources) and the other students to a group that used the resources. The performance of all three groups could then be compared. If the design were extended to a pre-test post-test design, baseline measures of performance and follow-up measures would be gathered. The treatment group would receive the intervention and the control group would not. Without the control group, there is no way of knowing if the change is due to the innovation or would have occurred anyway. The baseline measurement allows one to know if a change has taken place and whether that change is bigger for the experimental group than the control group.

As there were ethical issues involved in splitting a class into two and denying one-half video resources, the performance of the 2007 cohort of students, who had accessed the video resources covering the entire syllabus, was compared to the performance of the 2004 cohort, who had no access to video resources. From an experimental perspective, there are other possible confounding effects, as there is no way of knowing if the cohorts are the same in all important characteristics. Even had it been possible to randomly allocate students to one of two treatments groups, the design would be simplistic. In educational research, it is unlikely that the multitude of factors that can confound outcomes can be easily controlled. For example, changes in lecturers may have been involved, teachers teaching a second group may have different experiences than others, there may be different social groupings within classes, etc.

Recognising the limitations in terms of designing educational research using the experimental approach, this study has made use of ideas drawn from qualitative research. In particular it has adopted the triangulation approach. Mathison (1988) provided two perspectives on triangulation:

> Typically, through triangulating we expect various data sources and methods to lead to a singular proposition about the phenomenon being studied ... This alternative perspective takes into account that triangulation results in convergent, inconsistent, and contradictory evidence that must be rendered sensible by the researcher or evaluator (p. 13).

In this study, the researcher seeks to validate findings through the collection of multiple sources of data. An examination of those data sources should take into account both consistencies and inconsistencies in what the data reveal about how technology can enhance mathematics education.

> Methodological triangulation involves the use of multiple qualitative and/or quantitative methods to study the program. If the conclusions from each of the methods are the same, then validity is established (Guion 2002, p. 2).

In recent years, the combination of qualitative and quantitative methodologies has been more formally recognised as *mixed methods* approaches. Creswell (2003) defined the mixed methods approach:

> … a *mixed methods* approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g., consequence-oriented, problem-centered, and pluralistic). It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems. The data collection also involves gathering both numeric information (e.g., on instruments) as well as text information (e.g., on interviews) so that the final database represents both quantitative and qualitative information (p. 18 & 20).

Within each of these approaches to research, there are many designs possible for the collection of data. Further, the collection of data at each stage may involve a variety of techniques. In this study, the role of technology in improving mathematics education was examined using data generated from multiple methods and case studies. Methods include surveys, structured and semi-structured interviews, skills tests, reports and other documents available within the institution, observations by the participant researcher, notes taken by the researcher as she conducted the research, and conversations with students. It has also involved discussions with academic staff who teach the subjects and with students evoking their attitudes, recollections and observations. These sources of data are not always weighted equivalently as Draper (1995) wrote:

> … an "experts' " opinion is less valuable than that of a teacher who has tried the materials on students, and a teacher's opinion is less valuable than those of actual learners. Learner's opinions however are often less trustworthy than behavioural tests (e.g. assessment scores) … (p. 69).

When using the triangulation approach, the consistency of the data is highly desirable, with inconsistency indicating a need for further elaboration. When collecting evidence as part of an educational evaluation, there is often concern about the techniques used and, in particular, what is inferred from the data gathering. For example, performance on tests may be used as measures of learning or understanding when the measures may reflect other possibilities. As Alexander and Hedberg (1994) suggested:

> … it is not unreasonable to suspect that multiple choice questions and other such 'easily marked' assessment method may have been used, leaving the reader to guess whether the learners were being assessed on their ability to memorise information or on their understanding of the subject matter (p. 237).

The Basic Skills Tests and Mid-Session Test that form part of the assessments in MATH141 involve multiple-choice questions. To further discern what students were learning through the use of videos, assessment data were complemented by interviews and survey questions asking students about what impact the videos had on their learning and understanding. Student interview data and open-ended comments were analysed using methods first described by Glaser and Strauss (1967). Understanding of the learning needs of students and impact of technology on the learning of students has been determined through a process of categorising data, and splitting and splicing categories.

4.4 Literature Review - Video Learning Resources

> Mathematics is losing the hearts and minds of secondary students. Well-designed video programs can help win over these lost hearts and open minds to the beauty of mathematics (Wood & Petocz 1999, p. 227).

The literature revealed that video resources have better learning outcomes than visual-only or audio-only presentations (Kozma 1991). Video resources or resources combining audio and visual components have been used to improve a range of student learning outcomes including:

- motivation to learn and attitudes (Wood & Petocz 1999);
- enjoyment and interest in finding solutions (Overbaugh 1995);
- remembering and understanding of content (Jonassen et al. 1999);
- learning and transfer of learning (Choi & Johnson 2006);
- constructing rich mental representations that improve the transfer of knowledge (Chambel, Zahn & Finke 2004);
- problem-based learning (Overbaugh 1995);
- recall, comprehension and retention (Kozma 1991) and
- reinforcement of learning (LeeSing & Miles 1999; Mayer 2001; Moreno & Mayer 2001; Veronikas & Maushak 2005).

From a production or development perspective, it is useful to identify those aspects of videos that are associated with improved outcomes. These include:

Context

The context within which the mathematics is applied, for example, engineering or science, is a necessary prerequisite for learning successfully, particularly for topics that are difficult to understand. Audio-visual information can be used to provide this context and this 'afford[s] time for reflection, elaboration, and comparison process[es]' (Chambel, Zahn & Finke 2004, p. 2).

Visualisation of abstract mathematical notions

Pappas et al. (2002) investigated the use of Digital Interactive Video Technologies (DIVT) as dynamic software which could help students to increase understanding and learning of mathematics.

Videos of worked examples

Seeing examples being solved is considered helpful and welcomed by students (Foster 2002).

Presentation of real-life situations

Connection to real-life enhances problem based instruction for students (Choi & Johnson 2006).

Jacobs (2005a) and other educators discussed the advantages of educational practices such as providing ‘real-world examples, visualisation, interactivity, constructivism, self-paced learning and self-paced testing’ (p. 761). Caladine (1999) discussed video resources in the context of providing students with the opportunity to work at a *Time*, *Place* and *Pace* of their choosing. Students are able to work through complex mathematics questions in a different way. This allows them to have more influence over their learning and to understand how to solve mathematics problems. Kozma (1991) compared information on video with that in static text and found that video information could inform the dynamic properties of mental models more readily than static information such as textbooks.

Each approach has its own advantages and disadvantages and the literature (Wood & Petocz 1999; Pappas et al. 2002; Rees, Atkin & Zimmerman 2005) suggested that best practice was likely to involve the use of a variety of techniques and technologies so as to cater for the differing needs of students. From a production perspective, the literature is not as revealing in regard to which particular aspects of the videos create the desired learning outcomes. Analysis of the videos produced by (Wood & Petocz 1996; Petocz & Wood 1998) revealed a focus on portraying mathematical thinking in the ‘real’ world context, indeed a somewhat constructed setting, with the ‘word-person’ talking to the ‘mathematics-person’, with words and thoughts giving way to the mathematical expression of ideas. For example, in the *F-Files* video of Wood and Petocz (1996), the video theme was the detection of a murderer using exponential, trigonometric and discrete functions. The detectives chased the murderer using functions to connect the facts. In a second video, Petocz and Wood (1998) discussed the basic concepts of algebra in an engaging format to show students that algebra is a way of generalising real world problems and investigating mathematics further. Both videos were packaged with a booklet to expand mathematical ideas.

Foster (2002) found that students welcomed videos of worked solutions but he provided little explanation as to how the resources were designed or how they functioned.

Atkinson (2002) considered the worked example to be 'an instructional device that provides a model for solving a particular type of problem by presenting a solution in a step-by-step fashion' (p. 416). The model proposed by Atkinson (2002) involved a sequential presentation of problem states, emphasising problem subgoals and incorporating a second modality. Worked solutions similar to worked examples in textbooks are considered to be visually fixed in contrast to multimedia versions where it is possible to sequentially reveal the steps setting up what Renkl (1997) called *anticipative reasoning*. Students are able to anticipate the next step in the solution and then check.

Flevares and Perry (2001) discussed multiple modalities such as gestures, pictures, objects and writing, which can be used in addition to the spoken word in order to develop richer mental representations. Furthermore, the authors note that teachers consistently use 'nonspoken forms to communicate important conceptual and procedural information' (p. 304). Many of these modalities can also be used in multimedia resources such as video clips. Worked solutions allow for the use of multiple perspectives and imagery to help students understand structure and relationships (Skemp 1986). Graphics and animation, both static and dynamic, can also be used (Jacobs 2005a). Multimedia examples can be structured to exploit verbal or instructional explanations, and with lifelike characters or pedagogical agents to imitate non-verbal communication such as gaze and gesture (Atkinson 2007).

While Flevares and Perry (2001) concluded that gestures are essential in the instructional setting, they identify the possibility of cognitive overload if too many modalities are combined.

> Gesture which typically occurs naturally integrated with speech … appears to play an essential role in linking forms of information in face-to-face instructional settings. Although previous work … has indicated that students may become cognitively overloaded by presentation of information … Perhaps observing only two different modalities in combination is easier for students to process (and for teachers to produce) than representations presented in three or four modalities, but three or four modalities may provide the basis for a richer and more flexible mental representation (p. 343).

The literature, however, does not adequately address the many choices that must be made when producing video worked solutions as learning resources. Many of these decisions were left to the researcher, acting as a teacher, in determining how much or little to present, both in terms of text and visuals.

4.5 Positioning of Self

In qualitative methodologies it is often the case that the researcher becomes part of the study. In this study, the researcher who designed and evaluated the video resources has drawn on her experience as a mathematics lecturer in two countries, Iran and Australia. That experience extends from working one-on-one with individual students over the last fourteen years at both secondary and tertiary level to lecturing and tutoring mathematics subjects in Iran. As an example, two calculus based subjects (Mathematics I and II) included: functions (for example, exponential, logarithms, trigonometry, hyperbolic), domain and range, graphs, and inverse of them, limits and continuity, differentiation, application of derivatives, integration, applications of definite integrals, methods of integration, applications of integration, matrices and determinants, polar coordinates, infinite sequences and series, vectors and geometry of space, partial derivatives, multiple integrals (double integrals in polar form and triple integrals in cylindrical and spherical coordinates), substitutions in multiple integrals, integrations in vectors fields (Greens' theorem, Stokes' theorem and the Divergence theorem). Other subjects taught in Iran include Differential Equations, Engineering Mathematics, Numerical Analysis and Operational Research. In Australia, the researcher's experience has involved tutoring for the subject of interest in this study, MATH141, and lecturing and tutoring for the follow-on subject MATH142. She was also employed to work on MATH151, an introductory subject for science students, covering similar topics but at a lower level than MATH141. Working as a tutor for MATH141 gave first-hand observation of students' difficulties and also helped her to determine which of approaches were successful in helping students learn how to perform the various mathematical skills.

There were several perceptions that shaped the development of resources. These included:

- Some students understand how to do a mathematics problem once they see a worked solution. For these students, the worked solution is possibly a reminder of what they formerly learned and had forgotten.
- Some students are unable even to start a solution. They may need to learn how to conceptualise the start of solutions. For these students, it may be useful to hear the thought processes that lead the solver to write down the first line of the solution.
- Fully worked solutions help students who know how to start a solution but 'lose their way' on the way to their answer.
- Some students need to revisit definitions and/or rules before attempting questions.
- Students can be alerted to common errors by comments such as 'Don't forget the exponent'.

The researcher's teaching experience has suggested appropriate ways to write solutions and when theory review was required. This has led to the following advice:

- Refresh students' minds during teaching by writing some useful formulae in the corner of the whiteboard.
- If the current topic that you are going to teach is related to a previous topic, allocate the first few minutes to remind students what was taught previously.
- Tell students what today's subject is and create some questions, if possible related to real life, before beginning to teach.
- Write very neatly and legibly while explaining the solution.
- Align 'equal' (=) signs.
- Use different whiteboard marker colours to emphasise important parts of a definition or worked solution.
- Put an 'asterisk' or write 'NOTE' on lines of working where students typically make mistakes.
- For questions which involve several steps or where there is a need to find unknowns, tell students to draw a rectangle for every finding and unknown which help them to 'not get lost' in their worked solution.

- 'Solve' the question, showing common errors and drawn a big cross on the board next to the incorrect 'solution'. This reminds students that this is not right. Tell students to check their progress.
- Throughout the development of solutions, keep asking for students' ideas. For example, ask them 'What do we do for the next step?', and encourage them to answer your question as this helps them to think.
- When asking a question, give students enough time to answer as some students need to review the question in their mind.
- Divide your attention between students. Don't relate to just a few smart students, as involving all students invites and motivates them to learning and discussion.
- Encourage students to have practice before attending their class.
- Be gentle when correcting students.
- Announce in the first week of session that in randomly selected weeks, you will have quizzes consisting of one or two questions, particularly from previous exams, and students will be rewarded for their grade (unannounced assessment is not permitted at the University of Wollongong).
- Allocate the last few minutes of the class to a short review of what was taught and pose a question for the topic that you are going to teach next time.
- Try to avoid speaking in a monotone. Vary pitch and volume to prevent students falling asleep!!

Teaching experience can not resolve all questions. Student evaluation was used to answer questions such as

- How much explanation is required in presenting a solution?
- What production techniques are preferred?
- Should solutions be revealed character-by-character or line-by-line?

There were also several pragmatic issues that impacted on the design and evaluation of video resources. These included:

- As the researcher had English as a second language, a native-speaker of English was involved in the provision of voice-overs, thus making costing of the techniques difficult.
- Time constraints led to design constraints. For example, the video resources provided a theory refresher and review rather than an introduction to topics or other approaches such as developing ways that students may experience and construct mathematics.
- The subject that video resources were designed for was a skills-based subject, with a set curriculum and pedagogical approach, changes to which fell outside the prerogative of the researcher.

Technical resources accessible at the University of Wollongong also imposed direction in terms of investigating potential technologies. The direction and explorations were again influenced by one’s perceptions as researcher and developer. One of the aims of the investigation into the use of technology for improving mathematics education was to develop processes that were sustainable. The resources to be developed were to be a subset of resources likely to be required by students learning mathematics and, as such, the approach needed to be suitable for adoption by others. In the first instance, the choice of technologies involved preliminary use and evaluation by the developer. As described in Section 4.3, evaluating the quality of the video resources through interview was to be undertaken by students in the early stages of development after 20 mathematics problems were developed. Later, the finished video resources were evaluated in terms of student learning outcomes.

4.6 Preliminary Investigations: Discounting Technologies, Limiting Scope

To assist students in developing the expertise they had gained at high school in basic mathematical skills and manipulations and to help them master the techniques that are used in first year university mathematics, it was decided to create learning resources that provided fully worked solutions to sample mathematics questions. Fully worked solutions can be written in LaTeX, converted to PDF and distributed to students via a WebCT site. Reading a worked solution, however, does not necessarily help students who cannot conceptualise how to approach the question and this was considered an important consideration. For this reason, a decision was made to produce video worked solutions.

From the decision to develop full worked solutions for students, several questions were evident. These included:

- What sort of resources should be made available to students?
- What method should be used to produce the mathematical symbols required in the development of solutions?
- What methods should be used to produce the video resources?
- How should the resources be made available to students?

4.6.1 Mathematical Notation

One of the problems in providing mathematics and statistics resources on the web concerns mathematical notation. Chan (2004) referred to the difficulties associated with teaching mathematics in an online learning environment '… WebCT does not support mathematical symbol[s], it is difficult to express an equation or a formula during the discussion' (p. 8). Foster (2003) documented,

> The presentation of online randomized assessments or exercises requires the dynamic use of maths rendering. This can be achieved using MathML, and this is now being used in both commercial Virtual Learning Environments (VLEs) and in stand-alone assessment engines. …. [re assessment problems] there are no assessment tools directly linked into these VLEs that can accept symbolic answers directly input by the student. The best that commercial VLEs can offer at present are questions that can include maths symbolism via MathML but the student cannot enter answers involving maths symbols. This is generally perceived as inadequate for HE, even at levels 0 and 1 (p. 147).

In providing electronic learning resources for mathematics subjects, the problem is how to best display mathematical formulae on a webpage. As HTML does not support mathematical notation, the use of Mathematical Markup Language (MathML) was investigated. MathML has tags that describe mathematical symbols. MathML code can be written using editors such as Sciwriter, MathType and MathML.NET Control. A negative feature of using MathML is that students are required to have the necessary skills to download and install MathPlayer in order to display content produced by MathML on their browser. It is well known that when students experience difficulty in accessing technology, such as installing software on their computers, they are discouraged from using computers in their learning (Owston 1997; Daugherty & Funke 1998). It was therefore decided that an approach that required students to install software on their computers was unsuitable.

It is possible to remove the requirement for students to install ‘MathPlayer’ by converting a webpage that has been created by ‘MathML.NET Control’ editor to a graphics file, such as ‘jpg’ or ‘gif’. This produces images that clearly display mathematical symbols. These images can be created in black and white and have small file sizes, which means that students with low bandwidth connections can easily download the content of a webpage that combines HTML and MathML figures. Creating the mathematical questions and worked solutions in this way was considered but rejected because the question, answer and worked solution can be obtained from the video solution only as static images.

Publication software such as LaTeX can be used to create mathematical expressions that appear typeset and the professionally produced look can be viewed as ‘better’ than handwriting. Software such as LaTeX, however, produces static images and text that does not readily convert to video files in which the character-by-character development of a solution is visible.

4.6.2 Other Development Systems

Prior to creating the video solutions, some consideration was given to producing the video solution using Macromedia Flash (an animation program). This approach was not adopted due to the training necessary to use the program. It was thought that this barrier would deter many academics from developing video solutions. The technology chosen allows learning resources to be created with significantly less training.

The creation of video solution such as the inclusion of the person completing the solutions or the use of a 'talking head' inserted in the corner of the video was also considered; however it was considered that such images could date the resources, increase the file size and raise issues about the representation of different student groups. The bandwidth cost in terms of speed and size of downloads was considered too high with these approaches.

4.6.3 Delivery Systems

When this study started, the University of Wollongong did not have access to a version of WebCT containing an equation editor. Recently, the University of Wollongong changed from WebCT to Blackboard Vista, which provides one. This has not been evaluated for the purposes of this study.

4.6.4 Limiting Scope

There are many issues in mathematics education which remain to be investigated and resolved. Where a question has a 'popular' wrong answer, should a 'solution' that obtains the wrong answer be provided, following an explanation as to why it is wrong? Or will providing a video with an incorrect solution confuse students? If a question can be solved in more than one way, should multiple solutions techniques be provided? For example, see the Functions section, question 3 on the attached DVD. Would multiple worked solutions help students appreciate that there is not necessarily a 'right way' to solve a mathematics question, or would it confuse them? What types of educational resources will best aid struggling students to learn and understand mathematics? Such questions as these remain beyond the scope of this thesis.

4.7 Design Decisions

Based on the 'change evaluation', the 'next step interview' with the lecturer and an analysis of student performance in the mathematics topics in MATH141 (Chapter 6), the literature and the researcher's perspective on how to assist students to learn

(Sections 4.4 & 4.5), several design decisions were made in relation to the development of learning support resources for students in MATH141. These decisions related to:

- clarification of aims and objectives of video resources,
- specifications of video resources required,
- specifications relating to production techniques and
- specifications for how the video resources would be delivered to students.

4.7.1 Aims and Objectives

In terms of student learning, the video resources were developed in the first instance to assist students in mastering the techniques introduced in high school and used in their first four weeks at university and by doing this, to assist them in making the transition between high school mathematics and university level mathematics.

After the first outcome evaluation in 2006 these aims were modified to include the development of resources to support student learning of new skills and support student learning throughout the entire subject.

In terms of production methods, the aims were to:

- produce resources of sufficiently high quality that they could be considered an appropriate demonstration of using video resources,
- determine which system of production is most effective and hence most viable for longer term use, for adoption by others and for maintaining and extending the resources and
- document the systems of production to facilitate:
    - evaluation of the production process
    - further use.

4.7.2 Specification of Resources Required

The initial specifications involved:

- developing fully worked video solutions combined with an audio track to help students to learn how to solve mathematics problems,
- developing worked solutions to twenty questions students had met in their initial basic skills test,
- using the audio track for the solver to explain the evolution of their thought processes as they tackle the question, (It was expected that this would help students understand the thought processes that lead to the first line of a solution and how to think about problem solving.)
- employing the visual component of the videos to show the character-by-character development of the solution to help students learn step by step and
- developing a printed solution of a fully worked solution to determine if development of video resources was warranted.

These specifications are related to two of the objective of this thesis (Section 1.3).

After the end of the first session and following evaluation of learning outcomes, the specifications were extended to:

- create additional video worked solutions for topics already covered,
- extend the video resources to cover new topics,
- create additional refreshers or reviews of topics and
- develop video resources for past exams papers in 2005 and 2006.

After the Mid-Session Test in 2006, essential formulae or definitions were included in new video solutions as a refresher for students (Table 4.2). For examples of refreshers see the section on Integrals and the section on Surds on the attached DVD which defines what a conjugate is and then explains how to use the conjugate to rationalise the denominator. Students were asked to complete the example using the hint on how to use conjugates and they were advised ‘To see this done, try Question 1’, and a link was provided to the solution. There were refreshers for the topics: indices, surds, logarithms, factorisation, algebraic fractions, quadratic equations, and zero of functions to demonstrate definitions, formulae and rules.

Table 4.2 Number of Video Solutions Developed During 2006 and 2007

Topics	Solutions 2006	Solutions 2007	Review 2006	Review 2007
Fundamentals				
Indices	10	10	Yes	Yes
Surds	8	8	-	Yes
Logarithms	8	9	-	Yes
Factorisation	2	4	Yes	Yes
Algebraic Fractions	6	7	-	Yes
Quadratic Equations	3	3	Yes	Yes
Geometry	6	6	-	-
Trigonometry	6	9	-	-
Factorial n!	1	1	-	-
Functions			Yes	Yes
Domain	5	5	-	-
Evaluating Functions	2	3	-	-
Zero of Functions	1	1	Yes	Yes
Even and Odd Functions	1	1	-	-
Combining Functions	1	1	-	-
Composition of Functions	2	3	-	-
One-to-one and Inverse Functions	0	1	-	-
Inverse Trigonometric Functions	0	1	-	-
Hyperbolic Functions	0	3	-	-
Inverse Hyperbolic Functions	0	3	-	-
Binomial Theorem	1	1	-	-
Absolute Value Function	1	1	-	-
Find y in terms of x	1	1	-	-
Limits and Continuity				
Limits	2	9	-	-
Continuous Function	1	1	-	-
Differentiation				
Elementary Differentiation	6	9	-	-
Logarithmic Differentiation	0	1	-	-
Derivative of Trigonometric Functions	4	5	-	-
Derivative of an Inverse Trigonometric Functions	0	1	-	-
Derivative of Hyperbolic Functions	1	2	-	-
Derivative of Inverse Hyperbolic Functions	0	1	-	-
Implicit Differentiation	1	2	-	-
Derivative of Parametric Equations	1	3		
Matrices and Determinants				
Index and Sigma Notation	1	1	-	-
Symmetric Matrix	1	1	-	-
Matrix Application to Systems of Equations	8	8	-	-
Determinants	1	1	-	-
Polar Co-ordinates	3	4		
Integration				
Definite Integral	3	4	-	-
Methods : Integrals by Inspection	0	1	-	-
Methods: Using Integral Tables	2	3	-	-
Methods: Algebraic Substitution	0	2	-	-
Vectors				
Unit Vectors	0	1	-	-
Projections	0	1	-	-
Dot product of Two Vectors	0	2	-	-
Cross Product of Two Vectors	0	2	-	-
Miscellaneous	9	10	-	-

4.7.3 Specifications - Production Techniques

Two available video production technologies were selected. This provided the opportunity to develop and compare different video resources with different visual characteristics. The first of these production methods was eBeam (http://www.e-beam.com/), which captures pen strokes using an interactive whiteboard technology, and the second involved the use of an ordinary video camera mounted on a copy stand. The evaluation of using these technologies from a production perspective is described in Section 4.8. The basic set-up of each technology is described providing the settings used to record the solutions (e.g. audio and video camera settings) and post-production processing of the solutions (e.g. file formats and compressing). This is provided so that faculty adapting these techniques for their own requirements can do so without having to ‘reinvent the wheel’.

In the eBeam method, each stroke of the pen appears on the screen as if by magic – the ‘actor’s’ hand and the pen were invisible. In the second production method, the hand of the actor and the pen are both visible. Screen captures from the two methods are shown in Figures 4.1 and 4.2.

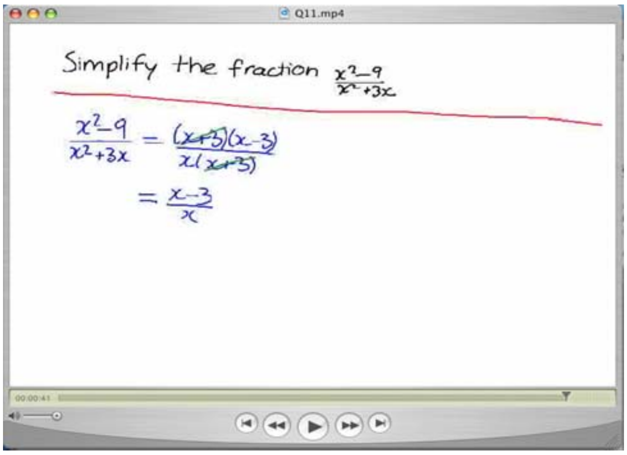


Figure 4.1 Screen Capture of QuickTime Replay of an eBeam Worked Solution: Hand not Visible

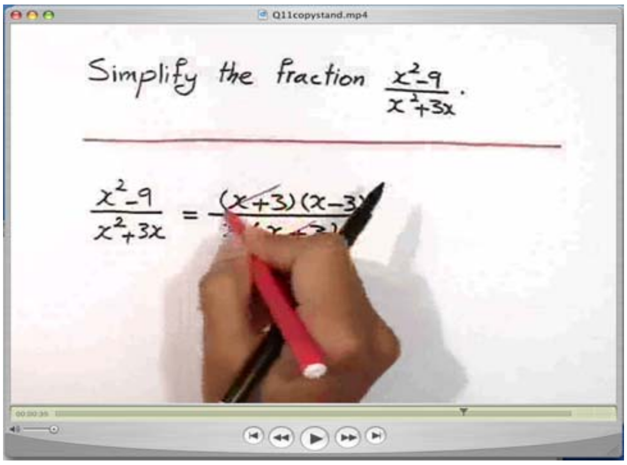


Figure 4.2 Screen Capture of QuickTime Replay of a Video Camera Worked Solution: Hand Visible

4.7.4 Specifications - Delivery

The delivery specifications were minimal, with experience being used to determine the most effective mechanism. This yielded the following recommendations.

- Video learning resources were intended to be used asynchronously as a supplementary support to students' studies.
- Video resources were to be accessible through the web. As students at the University of Wollongong had access to WebCT, and more recently Blackboard Vista, it was decided to deliver the video resources as they became available, along with other learning resources, through WebCT, giving students the flexibility of accessing them where and when they needed to. This was also important as resources could be added to the collection throughout the session of study.
- The video resources were to be delivered on a DVD or CD-ROM, so that students could work offline in either a PC or Macintosh environment, however this did not emerge as a priority. Uploading resources as they were developed meant that students had access to substantially more resources than if all were to be complete at the commencement of the session. CD-ROMs were used to distribute worked solutions as part of the formative evaluation of the solutions.
- Each webpage was written using html code rather than with WYSIWG (What You See Is What You Get) applications such as Dreamweaver, this was partly

a cost issue, in that the project had minimal funding. It was an issue of support as well, since two supervisors coded directly in html, but it was also an attempt to minimise the code actually used so that each page could be produced as efficiently as possible. Often when Microsoft Office documents are converted to html, the resultant code is overly long thus creating larger than necessary file sizes which, in turn, leads to longer download times.

4.8 Documenting the Video Production Process

Two of the aims in relation to development of the video resources involved a comparison of the production systems, eBeam and the mounted video camera, from a teaching point of view. The first aim involved documenting the production process of each, in order to evaluate them from the production perspective. The second was to make available appropriate documentation so as to facilitate further use.

Three processes that form part of the documentation process and which are common to both production techniques are:

- creating worked solutions as static images,
- recording the audio and
- compressing the video files to produce the final video.

4.8.1 First Production Method: eBeam

At the time of writing, there are several technologies on the market that capture pen strokes from a whiteboard. These include eBeam (http://www.e-beam.com/), Mimio, Herma and Smart Board. At the time that this pilot project started (2005), however, only eBeam was available at the University of Wollongong, which is why it was chosen for the first production method.

There are two modes for eBeam: projection mode and whiteboard mode. The eBeam projection mode can be used to turn the whiteboard into an interactive whiteboard and the eBeam whiteboard mode can transmit/convert all notes and diagrams written on the whiteboard to a Windows or an Apple computer as a digital file as they are written. They can then be viewed, edited, shared, saved and printed.

To use eBeam in whiteboard mode an eBeam receiver was placed in the corner of a whiteboard, as shown in Figure 4.3, and the receiver was connected to a computer. The mathematics solution was then written on the whiteboard using standard whiteboard pens that were enclosed in sleeves. The sleeves transmitted their position to the receiver using ultrasound. The receiver, using triangulation, detected the position of the pen and the pen strokes were automatically recorded graphically by software saved on a Windows computer connected to the receiver, and converted to video. The capturing of a question is illustrated in Figure 4.3.

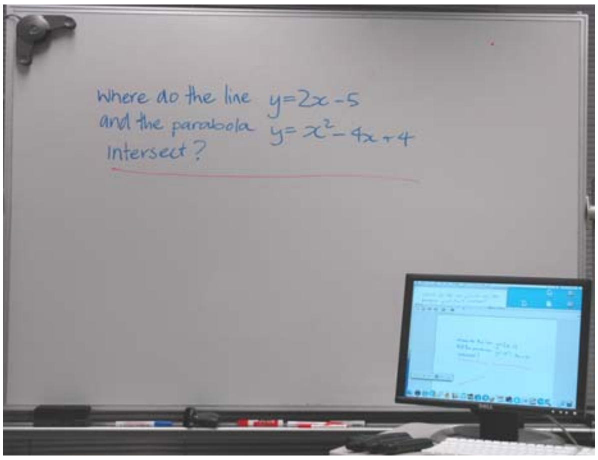


Figure 4.3 eBeam Apparatus

When recording video solutions using eBeam, the solver writes the solution on a whiteboard in much the same manner as would be done in a class. Only the pen strokes are recorded by eBeam. The solver is invisible on the video solution and the viewer simply sees an animation of a solution. The solution is regularly saved as it is developed. This is advantageous because, if required, a line can be erased from the whiteboard and deleted from the video file. The solver then resumes the solution from the last correct line. Lines were sometimes erased not because they were wrong but because it was decided that more detail was required at a particular point in the solution. The ability to erase lines and to restart solutions in this manner meant that partial solutions could be built upon.

The video files were then imported into the iMovie program on an Apple computer and edited. The resulting files needed to be edited for timing. If the solution was played at the speed it was recorded at, then the answer appeared at a rate that seemed very slow to a viewer. This slowness was partly due to the solver sometimes have to stop to think about what to write next and partly because it took more time to write a solution on a whiteboard than it would take to write on a sheet of paper. To produce a video in which the solution develops at a ‘natural’ speed the video file was edited using iMovie. The video solution was then compressed to decrease the file size and hence download time. This process is described in Section 4.8.5.

The initial learning involved in producing eBeam solutions was time consuming. A particularly frustrating problem was that, due to a software problem, the computer would repeatedly freeze during recording. When this happened, the only solution was to reboot the computer. This necessitated the regular saving of the worked solution. The manufacturer provided a software patch for this problem which was partly successful in reducing the number of times the process froze. A switch to running eBeam on a Windows computer also helped reduce this problem.

The ultrasound receiver only detected motion of the pens within a defined window. Before a solution was recorded, the area within which a solution could be detected had to be determined. Once it was determined, lines were drawn slightly outside this calibration region. This showed the solver within what region of the whiteboard the receiver would detect the solution. Once the calibration region had been determined, it was used for each solution recorded during that session. Provided that the receiver was not moved between recording sessions, the calibration window remained the same so under ideal circumstances, it only needed to be determined once, but of course such ideal circumstances did not always obtain. When writing a solution, care also had to be taken to ensure that the pressure-sensitive switches in the eBeam sleeves were activated. An additional problem with the software was that when the solver wrote a multi-stroke character, for example an ‘x’, not all of the pen strokes might be recorded. When this happened it was not clear to the viewer what the symbol was. If this was noticed at the time of recording, the line was re-recorded. If it was only noticed afterwards, the entire solution had to be re-recorded. A minor disadvantage with eBeam was that writing in a straight line across a whiteboard is an acquired skill.

When the problem was solved, questions and worked solutions were written on the whiteboard and then they were saved onto the Windows computer. To combine the eBeam file with a recorded audio (Section 4.8.4) the following steps were taken:

- whiteboard mode was used for capturing,
- a USB drive was used to transfer the files from Windows computer to Apple G5 for editing,
- the file was exported from eBeam in the Digital Video (DV) format,
- the Digital Video (DV) file was imported into iMovie and
- the audio was captured in iMovie.

4.8.2 Second Production Method: Video Camera

The problems experienced using eBeam, particularly the repeated freezing of the computer screen, led to the development of video camera production techniques to create the video resources. Perhaps the most obvious video camera production style would be to use a video camera to record a person solving a problem on a whiteboard or blackboard. This approach has been used at the University of Wollongong for the Summertime Maths project (http://www.math.uow.edu.au/subjects/summer/). However, in this work it was decided not to create a video of a teacher standing at a whiteboard. There were several reasons for this decision. It was believed that the image of the teacher could be a distraction. Also there was a concern that the solution would not be rendered large enough to be legible. As the video files were to be delivered via internet, the size of the file had to be limited so that students could access them from limited bandwidth connections. To achieve the same file sizes for video including a teacher at a board, greater level of file compression would be required. This could result in a lower visual quality. Furthermore, using an on-screen performer required at least two people to record the video, one to write the worked solutions and another to record.

For the video camera production method, the video resources were captured by using an ordinary video camera designed for home use, mounted on a copy stand about 40cm above an A4 sheet of white paper which was placed on the platen of the copy stand underneath the camera. The solution was then written on the paper, as shown in Figure

4.4, by the same person who operated the video capture equipment. The paper was taped to the desk to prevent it moving while the solution was being written. The solver wrote each solution on paper under the camera, drawing emphasis to certain parts of the text by pointing or circling. The video output from the camera was captured by an Apple G5 computer which was connected to the camera by a FireWire cable (Figure 4.4). The video was captured using iMovie. The video files were edited in iMovie, removing the writing of the question and speeding up the solution for the reasons noted above. In contrast to eBeam, the initial learning involved in producing solutions using the video camera was straightforward. One of the main advantages of this technology is its reliability compared to eBeam.

Figure 4.4 Video Camera and Copy Stand Capture Apparatus

Initially, the video camera was used in automatic mode. However, the automatic iris resulted in a video in which the background appeared too dark. This created a shadow around and inside the text, degrading the visual quality of the solution. As seen on the computer screen in the illustration above, the problem was eliminated through selecting manual iris and opening or closing the iris to obtain the appropriate exposure.

The surrounds and the paper underneath were light in colour, producing bright backgrounds that did not distract. The solution was written using a medium overhead projector pen. Investigations revealed that the kind of pen used was crucial. A medium pen was found to result in a solid line when recorded. Experimentation with different pens was necessary as some pens caused the ink to diffuse into the paper and this produced a fuzzy image on the video. In contrast to eBeam, it was found that colours were poorly reproduced: dark blue, brown, dark green and purple essentially appeared black. Thus the colours available were black, green and red.

When the video camera was placed 40cm above the paper there was, as with eBeam, a window in which the solution could be recorded. Prior to recording, the size and the location of this window had to be determined. This was achieved by placing a ruler on the sheet and determining the location at which its position was not recorded by the video. A calibration box was then drawn around the window. The box was just outside the window of detection and provided guidance to where the solution should be placed. For each new solution the calibration region had to be re-determined because each sheet of A4 could not be placed in precisely the same position. The need for a calibration region could be removed by increasing the height at which the video camera was placed so that the whole of the sheet was within the field of view of the video camera. However, whether this is desirable depends upon the size and quality of the handwriting that is being recorded, as the final image size diminishes if the video camera is placed at a distance greater than 40cm. When the video was compressed (Section 4.8.5) to decrease download time, it became increasingly difficult to read the solution. For problems with short answers, the video camera was sometimes lowered to 38cm. This increased the size of the text when the video was compressed, and increased the legibility of the solution. The only way to achieve this effect in eBeam was for the solver to write the solution 'bigger'. The need to re-determine the calibration window for every recording during a session was a disadvantage of this technology compared to eBeam.

In this approach the solver was effectively being recorded writing a solution on paper. In the recording, the pen and hand of the solver appeared in addition to the developing solution. In theory the solution could be edited through using liquid paper on a mistake and rerecording the solution from the last correct line. However, the appearance of the hand in the solution made this problematic because, when the solution is rerecorded, the hand must be placed in exactly the same location as it was at the end of the last correct line. If this was not done, and it is not easy to correctly align the hand, when the finished video was viewed the hand did not move continuously, but jumped within the solution. This created a distraction when the video was viewed. The outcome was that when an error was made, the solution had to be re-recorded from the beginning. In practice this meant that it was very rare for a solution to be able to be completely recorded at the first attempt. An acceptable solution was usually recorded on the second or third attempt, although for one memorable problem an acceptable solution was recorded only on the twelfth take. As the number of attempts to record a solution increased, there was a growing feeling of anger and frustration by the solver – particularly if the error was relatively minor and occurred towards the end of the solution.

Initially, the video showed the question being written, followed by the developing solution. In later video resources it was recognised that there is no need for the student to see the question being written. Subsequently, the writing of the question was removed from the video during the editing process. Therefore, the video starts with the question already written. Later it was found that when it is necessary to write formulae for a question, in order to reduce the file size, it is better to write the formulae before recording, to then hide them with sheet of white paper and gradually reveal them as needed and at a speed which enables students to follow and understand.

An attractive feature of the video camera technology was that the pen could be used to emphasise certain parts of the text by pointing and by either circling or underlining text. When doing this, the solver held the pen slightly above the paper so that the circling/underlining motion did not mark the paper. Thus the video camera technology has the capability to combine visual and aural emphasis. No attempt was made to emphasise text in this manner when recording solutions using eBeam because it would result in further pen strokes, which were considered to be distracting.

With both the eBeam and video camera technologies, the existence of a calibration region imposed a restriction on the type of question that could be answered because both the answer as well as the question had to fit within the calibration region. To solve this issue using the video camera, a second piece of paper could be used to record the rest of the solution. To use such a system, students would need to be instructed to refer to the first part of the solution, possibly through some numbering system.

4.8.3 Creating Worked Solutions as Static Images

In addition to a video solution, an answer and a worked solution are provided for each question. The question, final answer and worked solution were captured from the video solution as static images. In the beginning, the static images were created by pausing the video at the required frame in the media player and capturing the image using the ‘Print Screen’ button. Each image was then cropped, edited and saved as a jpg file using the Paint program. A second approach was tried in which a short movie was made by filming the completed solution for approximately three seconds. This short movie was then imported into iMovie and the frame was exported into BMP (bitmap) using ‘millions of colours’ with the option for quality – ‘medium’. The Print Screen button was then used and the final jpg image was created using Paint as described for the first method. The second method produced a better quality static image and, importantly, produced a smaller sized file.

It was found that if the written solutions were not discarded after being recorded, they could be used to create the same image in different formats.

4.8.4 Recording the Audio

The visual component was reinforced by an audio component in which the solver explained their thinking about the solution: explaining in a step-by-step sequence what had happened and was going to happen. The audio commentary was recorded to help students develop their own problem-solving skills.

Prior to recording the audio commentary, the video was edited to remove pauses. The audio was then recorded as the ‘voice artist’ watched the video solution. Initially the audio was captured using a clip-on microphone and fed into iMovie on an Apple computer. Subsequently, the microphone in the iSight camera was used. This proved to be slightly easier to operate as it could be hand-held and plugged directly into the computer. There was no difference in the audio quality produced by the two approaches. The resulting audio track was then combined with the video track using iMovie. The combined file was edited to ensure that the audio track proceeded at the same pace as the video image. The voice over was re-used to produce the audio commentary for the video camera solution.

One of the difficulties faced when recording the audio component was to know how much detail should be recorded. Should the solver merely give a general strategy at the beginning of the problem, ('For this type of problem we usually have to do x, y and z') or should they provide a step-by-step audio commentary? Audio solutions were classified into three styles: *brief*, only the main part of the solution is recoded; *simple*, the solution was recorded but the solver doesn't explain the working; and, *detailed*, in which the assumed knowledge of a question is described in addition to explaining the main part of the solution. Of course it was possible to record *brief*, *simple* and *detailed* audio tracks for each solution and thus provide students with the choice of audio track. However, this was not done due to the extra time required to record multiple audio tracks.

The possibility of recording the audio and video simultaneously was investigated, as recording the audio separately created extra work. Video resources were also developed by recording the audio and video tracks simultaneously, recording both components on the same iMovie track. This does not necessarily remove the need to edit the audio track, although it can speed up the process of producing the final deliverable video solution. Simultaneously recording both components, however, creates more areas in which mistakes can be made. If, for instance, the visual component is correct but there was an error on the audio it is difficult to edit and to re-record just the part of the audio containing the error. Another disadvantage of jointly recording both components occurs when the visual component is speeded up by using 'Effect' in iMovie. This has the effect of also speeding up the audio track, which distorts it. Also, if the video is speeded up over a period in which the solver is silent, then a noise is created on the audio track. This technical problem could be overcome by recording the visual and audio components on separate iMovie tracks.

Once a video solution exists, it is easy to remove the current audio track and record a new one. Hence, it is possible to provide audio tracks in a variety of languages for the same question and worked solution.

4.8.5 Compressing the Video Files to Produce the Final Videos

The video solutions produced by both the eBeam or video camera technologies were compressed before they were made available to students (either by uploading them onto WebCT or burning them onto a CD-ROM).

As video solutions were developed while the subject was being taught, it was decided that the primary mechanism for distributing video files would be through the subject WebCT site. It was therefore essential that students working at home could download the files over the bandwidth of a dial-up internet connection. To minimise download time the combined audio-visual file was compressed in iMovie to reduce its size, even though compression causes a reduction in the quality of the pictures and sound. As some students used an Apple computer, while others used a Windows computer, the compressed file was provided in both formats. Compressed video solutions were therefore produced as ‘mp4’ files, for Apple computers, and ‘avi’ files, for Windows computers. The software required to play these formats, QuickTime for ‘mp4’ and Windows Media Player for ‘avi’, was supplied as part of the operating system on the computer. Although producing the files in a second format increased the time taken to produce the final product, it was thought vital that students could watch the video without having to install additional software on their computer. In 2007, a link to download QuickTime was added to the homepage of video resources for those students who wanted to access videos in the ‘mp4’ format (Section 4.9). The advantages of the ‘mp4’ format were that the picture quality was better and also the file size was smaller in comparison with the ‘avi’ format, so that it took less time to download the video solution.

To illustrate the compression ratios obtained, two examples are presented. An iMovie file for a question on logarithms was 197.1 MB in its raw format. After compression the file size was reduced to 948 KB (mp4) and 4.9 MB (avi). An iMovie file for a question on matrices was 1.3 GB in its raw format. After compression, the file size was reduced to 6.7 MB (mp4) and 41.2 MB (avi).

For production of the final video solutions, the settings given in Tables 4.3 and 4.4 were used for audio and video. These parameters were chosen to optimise the video and audio quality while minimising the file size.

Table 4.3 Video Settings for the Video Camera and eBeam Technologies

Video	Windows	Apple
Compression	Cinepak	Na
Depth	Millions of Colours	Na
Quality	Low	Na
Frame Rate	8	8
Key Frame Rate	24	Every-64 frame
Data Rate	360 kbits/sec	128 kbits/sec
Image Size	Na	640x480 VGA
Video Format	Na	MPEG-4 Improved

Table 4.4 Audio Settings for the Video Camera and eBeam Technologies

Audio	Windows	Apple
Audio Format	ALaw 2:1	AAC-LC(Music)
Channels	1	Mono
Output Sample Rate	22.05 KHz	32.000 KHz
Encoding Quality	Na	Better
Data rate	Na	32 kbits/sec
Sample Size	16	Na

The editing process and compression settings were the same for video solutions produced using both the eBeam and video camera technologies.

4.9 Other Approaches to Video Production

After the development and trial of the video resources (which will be reported in Chapter 5), the methodology for the development of resources was to pass to others. It is therefore valuable to detail successful design features, illustrating, through example, strategies for successful presentation that may be imitated and adapted or further developed by others for use in their teaching.

When there is a focus (as in this thesis) on the ‘style’ (or manner) of developing a written solution, there is also a need to appreciate how and why things are done the way they are, to observe and report on what works and what does not, and so on.

An individual presenter will use a variety of 'design features' in presenting the development of a written solution. These cover, *inter alia*,

- How the moving pen is used and the interaction with voice, hand and visual expression.
- Specific hints implicit in writing conventions, such as underlining and circling to highlight.
- Use of voice modulation.
- Use of face, especially eyes, for effect.

The illustration below of a successful implementation shows how one lecturer, who was the presenter as well as the designer, combines multiple features to engage with students via video, thus leading students to engage with a solution (Figure 4.5).

The task was the simplification of the expression '3m-2g-5g-4m'. The lecturer's words are presented verbatim in the commentary which follows. This illustrates preparation of user-friendly learning resources.

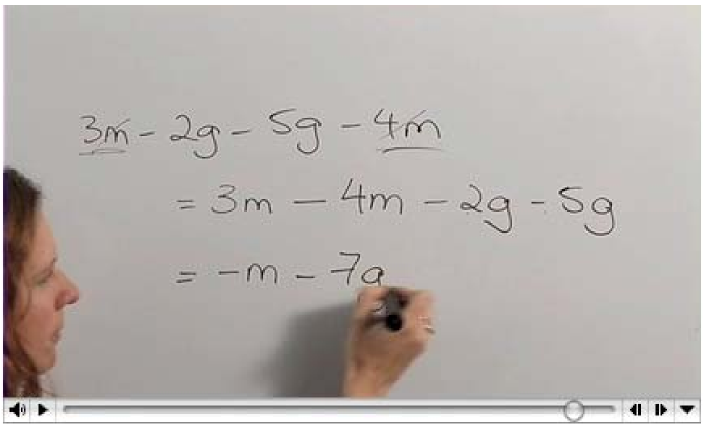


Figure 4.5 Solver is included in the Video

She begins the demonstration:

> Here [gesturing to the example on the board] we are going to simplify [end g] this algebraic expression [still gesturing]. What we need to do [gesture again] is to find like expressions, combine them together, add them [gestures] subtract them [gestures] or do whatever the expression asks us to do.

> So here we see we have three *m*s [gestures to the *m*s and underlines] and here we have four *m*s [gestures and underlines] so we need to combine them together remembering [exaggerated tone, begins to write the worked solution = 3m - 4m] that whatever sign is sitting outside of that expression [hand gesturing grouping the sign and expression] goes with that expression terms, so the negative sign with the 4m goes with the 4m, next we have the - 2g and the -5g [writes it up] is the last term.
>
> Now if you are starting [begin gesturing pointing] to lose track of the terms that you are writing out sometimes it can be useful to underline them or cross them out just lightly so you know you have put them on the next line.
>
> Here [wave] is a simple matter of just subtracting the 3 from the 4 and subtracting the negative 2 and the minus 5 [then writes as she continues] so we have 3-4 [points] is -1, you do not need to write the 1 so equals -m and -2-5 is -7 so we end up with -m-7g. Stops all and faces camera.

Indeed the only time the lecturer stopped gesturing was when she was writing, when the sentence spoken was longer than the time smooth gesture took and when the example was complete and she turned to face the camera, briefly pausing before continuing with the written solution.

Inevitably, different presenters have different styles. While all may use the technology advantageously, they will use it differently. The next example is one which was developed by the researcher as part of the work on this thesis (Figure 4.6). A native-speaker of English with a mathematics teaching background provided voice-overs. The solver's hand can be seen on the video, while neither the body of the solver nor the speaker is shown (on the attached DVD see differentiation section: question 1).

The video commences with the mathematical problem: Find $\frac{dy}{dx}$ if $y = \frac{1}{3}\cos 3x$.

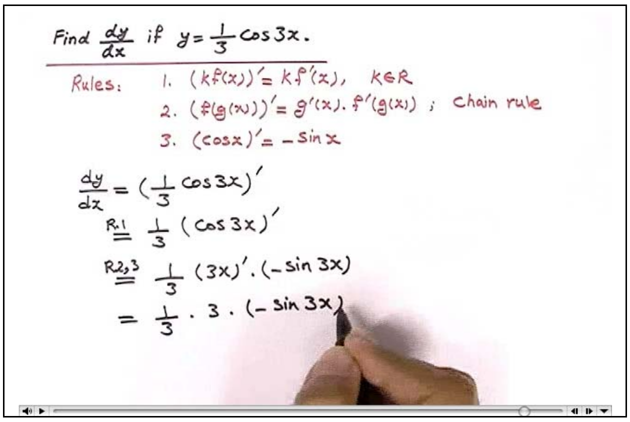


Figure 4.6 The Solver's Hand is included in the Video

> [Starts by reading the question] Find the derivative of y with respect to x if y equals 1/3 times cos of 3x.
>
> [Wrote the rules with red colour to distinguish] Recall the rules when we multiply f of x by a constant k the derivative is just k times the derivative of the function. '$K \in R$' is not spoken. The chain rule says the derivative of f of g of x is given by the derivative of the inner function g of x multiplied by the derivative of the outer function f of g of x. Rule 3 says the derivative of cos of x is minus sin of x.
>
> [changed the marker with black colour and restates and indicates rule] finding the derivative of 1/3 of cos3x first use rule 1 to take the constant 1/3 outside [circling] of the derivative of cos of 3x.
>
> Using the chain rule and rule 3 take the derivative of the inner function 3x [circling and pointing] and multiply by the derivative of the outer function [circling] which is minus sin of 3x. [circling and pointing] by noting that the derivative of 3x is 3 cancel the 3s [used red colour] and so the final answer is minus sin of 3x.

The two different approaches to the use of video in teaching and learning mathematics were favoured by different teachers. The preference for one method over the other could be based on several alternative of criteria. For example, those more comfortable with appearing on camera might prefer the similarity of that method to their role in a classroom. The methods also require different budgets. The video solutions in which the solver is seen were professionally produced and hence attracted real costs. The video solutions in which only the solver's hand was seen were produced primarily by the solver, and hence had minimal cost.

A comparative evaluation of the pedagogical effectiveness of the two productions styles would provide an insight into the return on the different levels of investment. While this is beyond the scope of this thesis, such a study would be a valuable addition to the research in this area.

4.10 Website Design

Dekkers (2004) suggested five principles for the design and development of web-based study materials. First of all, programs need to be both meaningful and relevant to students. In this study, an audit of skills was used to determine students' background mathematical knowledge in order to assure the relevancy of the materials provided.

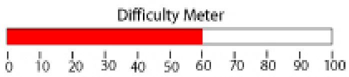
Secondly, Dekker suggested that learning needs to be organised around what he called 'competency development categories'. In this study the organisation was based on topics in which students were to demonstrate competency. Thirdly, individual needs and levels of ability need to be reflected in the materials and learning needs to be self-paced, independent and include self-assessment. The resources in this study were designed as self-instructional, self-paced and focused on self-assessment. Dekkers also believed in experiential learning within a 'supportive learning context'. In this study, students were provided with problems to solve after which they could access a variety of resources to check their worked solutions. They also were provided with a difficulty meter indicating how difficult other students found individual problems. Finally, he suggested that activities needed to reflect 'real life tasks or problems'. In this study, materials provided to students supported students' learning as these materials sought to focus specifically on the mathematics subject in which they were enrolled.

The video solutions were made available on the subject's WebCT site in 2006 and due to a merging of delivery systems, on the Blackboard Learning System (eLearning) site in 2007. In both instances there were instructions on the homepage to guide students' use of the website (Figure 4.7). The instructions asked students to turn off pop-up blockers that are located in the 'Tools' menu in Internet Explorer. The instructions given to students were as follows:

> There are a number of questions on each topic.
>
> 1. Attempt to solve each question.
> 2. When you have your solution, click on the Answer button under the question to see if your solution is correct.
> 3. If it is incorrect, click on either the Video Solution button or the Worked Solution button.
> 4. The Video Solution shows the solution line by line with an audio commentary. There are two kinds of Video Solutions one for Windows and one for Macintosh (Apple). Click on the button that suits your computer. "Video Solution-Mac" will work on Windows if the free QuickTime player has been installed. Download QuickTime
> 5. The Worked Solution is simply a written solution.

Following the instructions was an explanation of the 'difficulty meter':

The difficulty meter shows the percentage of students that answered the question incorrectly in the past. For instance, a difficulty of 60%



indicates that 60% of students answered incorrectly.

Please see print copy for figure 4.7

Figure 4.7 Homepage

In 2006, questions were listed on the website according to the order in which the mathematical concepts (algebra fractions, surds, logarithms, etc) were taught and in in 2007 they were arranged in alphabetic order. Further, the website was structured so that even without reading the instructions student could choose from a variety of solutions, definitions or additional questions as displayed in Figure 4.8.

Please see print copy for figure 4.8

Figure 4.8 Difficulty Meter and 'the Four Buttons' on a Typical Webpage

By making these video resources available in this way, an environment was created in which students decided upon their own navigational directions and this encouraged them to make connections between:

- correctly/incorrectly answered questions,
- their prior knowledge and
- the provided materials.

Each webpage was structured by breaking down the subject (MATH141) into units that appeared as a sequence of headings on the left-hand side of the webpage. Each heading contained two sub-headings: Definitions and Questions (Figure 4.8). Most questions had previously been used in tests. This allowed a ‘difficulty meter’ to be presented, indicating the percentage of students who answered the question incorrectly in the test. The difficulty meter provided students with an indication of the difficulty of each question. Using the difficulty meter as a guide, students could progress from the easiest question in the topic to more difficult ones, thus gradually building their mathematical skills step by step. The difficulty meter was created as a set of graphic files, one for each percentage setting ranging from five to ninety-five per cent in five per cent increments (Figure 4.9). The five per cent increments allowed students to clearly differentiate between problems of varying difficulty and meant that only twenty settings of the meter needed to be produced. The difficulty meter of the appropriate setting was inserted after each question on the webpage.

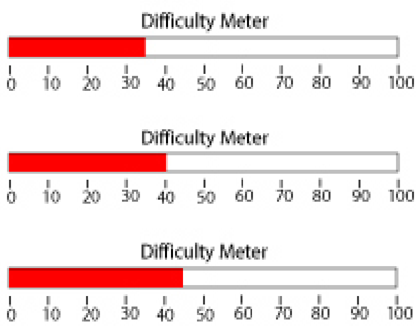


Figure 4.9 Difficulty Meter

As mentioned earlier, the navigational structure of the headings in 2006 reflected the order in which the material was developed in lectures, while in 2007 it was re-arranged into alphabetical order. Students choose for themselves, however, the sections to which they will navigate, whether to remind themselves of the definitions or to go straight to the questions, and whether to attempt easier or more difficult questions.

The links to definitions were included for students to refer to when they needed to recall prior knowledge, such as definitions and rules for the topic (Figure 4.10). This section assisted students to bring to mind the knowledge needed to work through a mathematical problem.

Please see print copy for figure 4.10

Figure 4.10 Definition and Rules

When the ‘Answer’ button was clicked, a pop-up widow appeared giving the answer and linking to the video solutions and the worked solution (Figure 4.11).

Please see print copy for figure 4.11

Figure 4.11 Pop-up Answer

If the ‘Worked Solution’ button is clicked, a new window is opened in which the worked solution is displayed as a jpg file. This window also contains links to the video solutions (Figure 4.12).

Please see print copy for figure 4.12

Figure 4.12 Worked Solution

If either of the video solution buttons is clicked, a new window is opened and the video solution plays in this window. There are no links from this webpage (Figure 4.13). Students can play the video as many times as they wish and may move forwards and backwards within the solution. They may choose to play the solution to a particular point, pause at that place and attempt to complete the solution themselves in full, or in part. They can restart the solution and compare their working with that of the remainder of the worked solution. This helps students to build up their mathematics knowledge and skills from simple to complex questions. Gagné (1965) believed that ‘skills need to be learned one at a time and … lower level skills must be mastered before higher level skills can be considered.’ (cited in Beevers and Paterson 2003, p.134).

Please see print copy for figure 4.13

Figure 4.13 Video Solution

A feature of the web design is that a student can choose a question on a topic with which they are having difficulty. They can then compare their solution with the answer. If their answer is wrong they can either try again or examine the worked solution. If they do not understand the worked solution, they can watch the video solution, simultaneously listening to the audio track. Comparing how they have attempted the question with how the solver has attempted the question provides a framework by which students can learn. Formative evaluation suggests that even when students know how to do a mathematics problem, comparison of their technique with the worked solution can still provide alternative strategies for problem solving or laying out of solutions.

The QuickTime media files did not need to be embedded in the website. The design of the website for Windows computers, however, was a little more difficult as JavaScript was needed to embed the 'avi' into the website. The ease with which html files can be written and embedded into the website was partly dependent on having well-defined naming conventions and structure for the organisation of the many files created (see attached DVD). The following hierarchy was used:

- There were the Index (html) file, the Concepts (html) file, the Banner (html, jpg) files and the Main (html) file.
- The Concepts (html) folder contained the mathematical topic files and tests.
- The Definitions (html) folder contained definition, rules, theory refreshers.
- The Questions (jpg) folder contained questions for different topics from past tests and exams.
- The Video solutions folder contained
- a Windows computer (avi, html) folder containing video developed for each question and corresponding html file and
- an Apple computer (mp4) folder containing Quicktime formatted video,
- The Answers (jpg, html) folder contained the answer captured from the last frame of the video.
- The Worked solutions (jpg, html) folder contained the worked solutions which were created from the last video frame.
- The Difficulty meters (jpg) folder contained the pictures indicating the percentage of wrong answers given to the question.

- The Mathsr folder contained the Cascading Style Sheet (css) that applied a style such as colour and font to the webpage.

In the next chapter, a comparison of learning outcomes is made for two cohorts of students, those completing the subject in 2004 when no resources were available and those completing the subject in 2007 when a set covering all topics was provided.

Chapter 5

Development of Video Resources

5.1 Introduction

In this chapter the primary concern is with gathering data to undertake formative evaluation to assist in the development of video learning resources. Data were collected to compare different production techniques, students' preferences for different resources and to determine if the resources were likely have any impact on students' learning.

To develop video learning resources, there was a need to compare the two technologies from the students' perspective in regard to both pedagogical differences as well as effectiveness for learning mathematics. In 2006, as the first step, data were collected via an interview and a survey with eleven students. A second survey was developed based on data collected from this small sample to confirm the results generated from the interviews. This survey was given to all MATH141 students after their Mid-Session Test in 2006. In the second stage of evaluation, it was necessary to collect data at the end of session in order to inform decisions made in regard to the development of the learning resources (Alexander & Hedberg 1994). The analysis of data gathered from the change evaluation was used to identify students' requirements for resources in 2007.

5.2 Development Stage - Evaluation of Production Processes

The project outlined in Chapter 4 started in February 2005. Most of the year was spent in developing proficiency in the technical aspects associated with the development of the video solutions and in issues related to the construction of the associated website.

From a production perspective, the question asked was ‘What are the criteria that make eBeam or the video camera appropriate technologies for the development of online resources for teaching and learning mathematics?’. Initially, video resources were developed using eBeam. In fact, having used both approaches, the researcher-developer’s preference, in the absence of technical problems, was to continue to use eBeam. The main reason for this is that is possible to edit the solutions as they are being developed, a function which is not possible using the video camera. This allows far quicker production than the current one or two hours to produce an individual solution with the video camera. Due to technical problems outlined in Chapter 4, however, a decision was made to switch to using a video camera because it was considered to be easy to use for most lecturers, with minimal training required to achieve a usable result. Also, as the technology was portable, video solutions could be created in different locations.

While the researcher was committed to exploring both production techniques and developing audio-visual solutions to trial with students, as of mid 2007, no one else has been interested in adopting these techniques, which have the advantage of producing resources with both an audio as well as a video component. Thus far, a staff member in the Science Faculty and a staff member in the Informatics Faculty have sought to develop their own mathematics audio-visual resources. They produced the visual component for worked solutions but floundered at the stage of adding the audio because they had no experience adding audio tracks to existing video. One of these staff members has begun using ‘Smartboard’, an eWhiteboard, which is an alternative production technique for audio-visual resources, but her work is only in the initial stages of development.

Indeed, the techniques appear too complex and time consuming for lecturers to commit themselves to the production of audio-visual mathematics learning resources. In order to institutionalise the production of such resources, it will be necessary either to provide funding to outsource the production, or to investigate whether the provision of training, in particular in audio delivery and capture, would facilitate a more wide-spread use of the techniques. Training would need to cover the entire process and be well documented. Alternatively, perhaps other, simpler production techniques could be identified. Since this study started, an Access Grid room (Chapter 8) has been installed at the University of Wollongong providing a further mechanism to create ‘digital ink’ through the use of Mimio, an interactive whiteboard, and, more recently, a touch-sensitive, electronic whiteboard. At a recent symposium, Dekkers (2007) estimated that the time taken for an experienced user to create a worked solution with voice-over using a tablet PC is 10 minutes. This compares to an estimated 30 minutes per solution for an experienced user of the two approaches trialled in this research. Dekkers’ solutions were made available for distant students. No comparison of quality is possible at this time, nor is a comparison of the time to reach experienced status. Based on Dekkers’ comments, however, the technique warrants investigation.

The $2000-$5000 cost of the PC tablets could also be an impediment for staff or departments lacking equipment budgets. For this project, the equipment budget required for the production of the video solutions was minimal, as the necessary equipment was made available through the Learning, Innovation and Future Technologies Laboratory (LIFT Lab) in the Centre for Educational Development and Interactive Resources (CEDIR) at the University of Wollongong. The fact that staff using this would need to leave their workspace for extended periods of time, however, is a potential impediment to the uptake of the process.

While the researcher found that both video camera and eBeam are effective technologies for the representation of mathematics notations on the World Wide Web, from an institutional perspective other techniques should probably be explored. This need to continue exploration is dependent upon the evaluation of the resources from a student learning perspective.

5.3 Development Stage - Student Evaluation of Resources

While other production techniques may need to be found in the long-term, several questions remain. From a student learning perspective the questions asked were:

- What, if any, are the pedagogical differences between online resources created with eBeam and those created with a video camera?
- What, if any, advantages or disadvantages to learning mathematics do these potential differences have?
- Do the video resources improve student learning outcomes?

In the development phase in 2006, three sets of data were collected. These involved:

Student interviews

In order to investigate these issues, eleven students were asked to complete mathematical problems using the resources developed with both methods: eBeam and video camera. They were asked after each question to check their solutions, and then to provide a comparative evaluation of the techniques. Answers obtained from the interviews were used to develop the mid-session survey.

Mid-session survey

Following the Mid-Session Test, a class survey was given to students to identify their attitudes towards the video resources and printed/worked solutions and thus to ascertain the impact on learning outcomes.

End of session Change Evaluation

In week 12, a survey was given to students with additional questions pertaining to the use of the videos and their role relative to other learning resources.

5.3.1 Evaluation - Student Interviews

The video recordings produced by the two methods were quite different in appearance. It was deemed appropriate, therefore, to compare the video resources in terms of their quality and effectiveness for student learning.

5.3.1.1 Aims

From a pedagogical point of view, the products appeared to be very similar. Close observation, however, elicited some differences that could impact on the effectiveness and efficiency of student learning. The absence of the ‘actor’s’ hand in the eBeam solutions may make it easier for students to follow the character-by-character development of the solution, because it was not masked by the hand. On the other hand, the presence of the ‘actor’s’ hand in the video camera productions could add to the learning experience as the ‘hand’ can be used to point out elements of the solution during its development. For example, it was possible to point back to earlier elements when they were re-used later in a solution. As these pedagogical differences are minor and might balance each other out, an evaluation of student perception and use of the video resources was carried out.

Unlike a lecture, during which students see a question being solved once, the video resources allow them to view this as many times as necessary. In addition, students may elect to see part of the solution and then pause the video while they attempt the next stage on their own. These are both advantages of the resources.

5.3.1.2 Method

The steps involved in the collection of evaluation data throughout the developmental phase of the research were as follows:

1. Ethics approval was obtained in order to invite students to participate in the trials of video resources (no. HE06/21). In the Participant Information Sheet (Appendix 5), students were informed that

The purpose of this research is to examine the impact of learning resources provided to you and to devise ways of:

- developing your knowledge and skills in a manner appropriate for your achievement of the subject objectives and
- supporting you in developing strategies that will enable you to learn more effectively.

2. Students were approached in lectures and asked to participate.
3. Nineteen students were given a CD-ROM containing 20 mathematics problems covering a variety of topics in both technologies. They were advised to watch the content. On half the discs the video camera solution always appeared first, on the other discs the eBeam solution always appeared first (Figures 5.1 & 5.2).

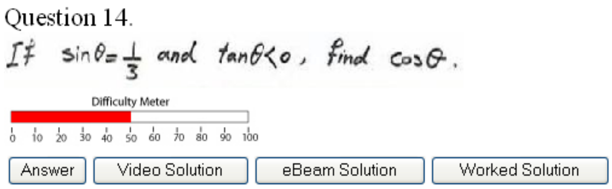


Figure 5.1 Video Camera Solution is the First Option

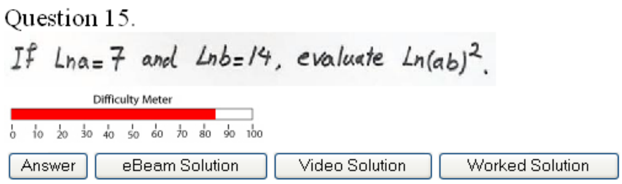


Figure 5.2 eBeam Solution is the First Option

4. After one week an email was sent to the students asking if they would be interviewed. Eleven students were interviewed.
5. In the interview, after signing the Consent Form (Appendix 8), each student was asked to solve a mathematics problem. After the student had attempted a question they clicked on the 'Answer' button to find out the answer.

- If their answer was correct they were given the option of viewing the eBeam version of the video solution. They were then given a second question to do, after which they were given the option of viewing the video camera solution. If students did not want to see the video solution, they were then asked to attempt another question.

- Students who incorrectly answered a question viewed the video solution and were then asked to attempt a similar question.

6. After each student had finished working their way through the mathematics questions, they answered a survey (Appendix 10) including questions on their frequency of use of the resources, the ease of use of the resources, the adequacy of the picture quality and voice on the video resources and their perceived impact on student understanding and learning (Table 5.1).

Table 5.1 Structured Interview and Survey Questions – Part 1

Use of the resources
Did you use the video solutions or the eBeam solutions to correct your mistakes and/or improve your understanding and learning of the mathematics covered in the skills test?
Options: No, Once or twice, Frequently
Does the on-screen hand in some of the **video solutions** help you to understand and learn mathematics?
Options: No, I didn't notice it, Yes
How did you find the use of the **video solutions** or the **eBeam solutions**?
Options: It was difficult and time consuming for me to use them, I found it difficult to use them, I solved questions well when I used them.
Quality of the resources
How was the picture quality of the **video solutions**?
How was the picture quality of the **eBeam solutions**?
How was the voice quality of the **video solutions** or the **eBeam solutions**?
Options: too poor to use, poor, good, more than adequate
Impact on learning
I believe that by using the **video solutions** or the **eBeam solutions** in this subject I could increase my capacity to understand and learn more.
Options: Not at all, I have tried and feel I have made no progress, I have tried and feel I have made limited progress, I have tried and feel I have more confidence to deal with mathematics

7. Students then took part in a structured interview at which they were asked questions about their preferences as to the use of detailed, simple or brief voice solutions, how to improve resources and their goals for learning in terms of solving problems or understanding concepts (Table 5.2).

Table 5.2 Structured Interview and Survey Questions – Part 2

Preference for detailed, simple or brief voice solutions For the video solutions or the eBeam solutions did you prefer the *simple* voice solution or the *detailed* voice solution?
How important are *detailed* voice solutions for helping you to understand and learn mathematics covered by the skills test?
Do you prefer to have voice for all the solution (*simple*) or just for main and central concepts (*brief*)?
In the eBeam or video solutions do you prefer *simple* voice or *detailed* voice?
How to improve resources How best can the video solutions resources be improved to help your understanding and learning of mathematics?
How best can the eBeam solutions resources be improved to help your understanding and learning of mathematics?
Do you have any other suggestions for the improvement of this subject?
Preference for just solving or understanding of the mathematics concepts Is your goal in learning mathematics to solve problems correctly or to understand the concepts?

5.3.1.3 Outcomes

The evaluation of the resources involved:

- a comparison of the production method and determination of whether the quality of the resources was at a suitable quality for testing whether students' learning could be enhanced through the video resources,
- identification of features within the resources which were seen as either user-friendly or problematic and
- the impact of the resources on student learning.

Comparing Technologies

Students expressed no clear preference for either the eBeam solutions or the video camera solutions. Some found the hand in the latter distracting, while others did not. Several students wanted a video that played quicker. This showed up as a slight disadvantage of the video camera technology because if the video was sped up too much, the hand would appear to scurry across the screen at great speed, which would be visually distracting. This problem did not arise with eBeam.

In developing the video resources, it was discovered that each of the two technologies had its own advantages and disadvantages. What had yet to be done was to determine whether the learning resources produced using either technology was technically of 'adequate quality' from a student perspective; were there aspects that needed improvement? Due to lack of time, it was not possible to provide answers to more than twenty questions in both formats for students in 2006. It was therefore, important to learn if students had a clear preference for solutions obtained using either the eBeam or the video camera, so that later production would use the best method.

Integrating Audio with Visual Cues

It was suggested that the audio could be made more useful if points in the video solution where common mistakes occur were noted. For example, when multiplying out an expression such as $-4(x-3)$, the audio could mention that a common error is to forget about the first negative sign and so obtain the wrong answer $-4x-12$. Without evidence it was assumed that for weak students, introducing errors might produce cognitive overload or 'too many things to think about' (Bills & Tall 1998, p. 106) and diminish the usefulness of the video solutions. It would be possible, however, to record two solutions to some problems: a correct solution and an incorrect solution. The student would be told that one solution was correct, but not which one. By watching the video and listening to the audio they would have to identify the wrong solution. This could help develop critical thinking skills.

Voice Modulation

By the time of the interviews two 'voice-over artists' had recorded the audio; one an undergraduate in the School of Mathematics and Applied Statistics and one a postgraduate with considerable mathematics teaching experience. The main attention had been on technical issues such as how to record the video, how to combine the audio with the visual component, how to compress the final video, etc. One of the students commented that one 'artist' had a much more well modulated voice, while the other had a much more monotonous voice. This was not something that had been considered. For further recordings, instructions were given to the 'artists' to help them modulate their voices more. In some institutions where a regular 'vocal artist' is used, it might be possible to provide training. Regarding the choice of 'artist', it is desirable to use a high quality voice, so that it does not distract from the content.

Layout

The design specifications suggested by the researcher called for the alignment of the equal signs. However, the dual objective of keeping the solution on one page conflicted at times with the need to write further across the page. As noted in Chapter 4, in both technologies there is a limited window in which text can be captured. For long solutions it is important to save space and it was found that one way to do this was to write more than one mathematical idea along a line. Some students found this distracting, as they found it hard to follow the steps and expressed a preference for each new idea to appear on a new line. One student wished to see all the equals' signs in an answer nicely aligned.

Character-by-Character or Line-by-Line Production

One student suggested that the eBeam solutions would be better if the solution appeared line-by-line, rather than character-by-character. It has been suggested that if the lines appeared one-by-one, it could be more difficult for students to understand the logic of the line that has just appeared. This could be a topic for further research.

Preferences for the Amount of Audio Explanation

One of the problems in recording audio referred to how much audio should be included in each solution. The results of the survey questions, 'Do you prefer to have voice for all the solution (simple) or just for main and central concepts (brief)?' and 'In the eBeam or video solutions do you prefer simple voice or detailed voice?', revealed that there was no common answer to this question. Students preferred *detailed* voice solutions for 'higher level' questions and *simple* and *brief* voice solutions for 'easier' questions, but disagreed upon what constitutes 'higher level' and 'easier'. One student expressed a strong preference for the *brief* voice solutions because 'It makes you think more for yourself and by doing that it helps you learn it better'. Some students wanted *brief* and *simple* voice solutions for all questions. This point of view depends upon the ability of the student. This was accurately described by one student who wrote 'Detailed [voice] solutions are good if you don't have any idea of what you're doing. But once you get a feel for the questions brief voice is adequate'. An instructor can use their judgment as to the type of question that most students have difficulty with and record an appropriate audio track. One student expressed a preference for varying the audio style within a question.

It was decided to provide a detailed audio for each question, because outlining the central concepts necessary for answering the question provides the best guidance for students wanting to understand the strategy needed to answer the question. It was believed that an understanding of the concepts will equip students to answer similar questions.

Students who do not like the audio have two options. Firstly, they can turn the volume down to zero and watch the video without the audio. Secondly, they can view a worked/print solution. Although some students felt that these two approaches are equivalent, this is not quite true. Students who do not know how to start an answer can watch the first part of the video solution (with no sound!), freeze the video at a particular spot and then try to finish the question.

It may appear difficult to understand the appeal of the *simple* voice solution, which provides no additional information to that provided in the visual component. However, students provided the following explanations for this preference:

> Simple voice solution is very important for me, as they help me to correct 'silly' mistakes.
>
> I prefer simple voice because as you hear word by word solution, concepts can click in your head.
>
> I preferred the simple voice solutions because in the questions that I had trouble with it guided me through the question.
>
> I would prefer the simple voice solution as it is more user friendly.

Students provided the following explanations for preferring the *detailed* voice solutions:

> It helps with problems I don't understand.
>
> Detailed voice was much more helpful as an understanding was gained.
>
> Detailed voice solution is very helpful in understanding the procedure required.
>
> It is very important as they help the step by step solution process for the questions.
>
> Very important, as it gives a good understanding of the base mathematics that will be required in higher levels of mathematics.

> If the student doesn't have a good background, then it's hard for student to understand the simple solution.

Learning Outcomes

The analysis of student preferences in regard to the amount of explanation necessary suggested that the video resources were helpful in understanding the procedures required. The resources from both technologies were found to be helpful both for students who were initially incorrect in their solution as well as for those students who correctly answered the question before checking the solution.

- By using the video solutions, even students who were initially incorrect could correctly answer new mathematics problems. After viewing the video or eBeam solutions, students who had given one or two incorrect answers were able to correctly answer two or three questions. This supported students' contention that they could understand the steps. Some students just needed to see the first step of a solution while others needed to watch whole video solution in order to correct their mistakes.
- Five students who correctly answered a question indicated that they found the video solution useful. For instance, the video solver may have used a different strategy than the student used to solve the problem. Even when the video solver used the same strategy as the student, some students found the video solution useful because it had a different way of 'laying-out' the solution. For example, the video solver may have developed the solution in a more logical manner, clearly outlining the process. Even in the few instances where the student preferred their own strategy to the one shown on the video, seeing the video solution was still useful, as they learned that there is not one 'correct' way to solve a problem. Three students, however, actively disliked seeing a problem solved in a method which was different from the one they had learned at high school.

The demand created by the initial resources also supported the notion that the resources could help improve learning outcomes. Students requested more video so that each topic in the syllabus was covered. It was suggested that for topics such as 'indices' and 'logarithms' where there are various 'rules', it would be useful to have an example illustrating the use of each rule. It was also suggested that some problems would benefit from having more than one strategy explained. For instance, for a particular problem there might be both a graphical and an algebraic approach to obtaining the solution.

5.3.2 Evaluation - After the Mid-Session Test 2006

A survey was developed from the earlier interviews (Section 5.3.1) and this was used to confirm and clarify the results produced by the small sample interviewed. This survey (Appendix 11) was given to students after the results of the Mid-Session Test were returned to students in week 9. It was administered to students during a break between two MATH141 lectures.

5.3.2.1 Aims

The aims of the survey were:

- to determine if the findings from the eleven students were characteristic of the larger class,
- to allow identification of the characteristics of students using the video resources, particularly identifying those who found them useful compared to those who did not,
- to identify how the video resources were being used and for what purpose,
- to enable an evaluation of the effectiveness of the video resources developed in terms of changes in performance,
- to determine if more of this type of video resource should be produced in the future and
- to find out how the video resources could be improved.

5.3.2.2 Method

The steps used in this phase of the data collection were:

1. Ethics approval was obtained from the University of Wollongong Ethics Committee (no. HE06/21).
2. At the end of a lecture, students were encouraged verbally to participate in the survey with instructions indicating that the aim was to identify the impact of video resources on students' learning. Students were informed in the Participant Information Sheet (Appendix 5) that

> The purpose of this research is to examine the impact of learning resources provided to you and to devise ways of:
>
> - developing your knowledge and skills in a manner appropriate for your achievement of the subject objectives and
> - supporting you in developing strategies that will enable you to learn more effectively.

3. The survey was distributed following the instructions, students completed the survey during the lecture break and the completed surveys were collected at the end of the break as students re-entered the lecture theatre.
4. Students answered questions on matters including their frequency of use of the video resources, their perceived impact on student understanding and learning, and the impact of video solutions on helping students to work independently (Table 5.3).

Table 5.3 Survey Questions – Part 1

Time to use video or worked solutions On average how much time did you spend using the **video solutions** or the **worked solutions** either through the website or from CD-ROM each week? *Options*: 0-2 hours per week, 3-5 hours per week, 6-8 hours per week, 9-11 hours per week, 12 or more hours per week
Impact on understanding and learning How important are the **video solutions** for helping you to understand and learn the mathematics covered by the Basic Skills Review?
How important are the **worked solutions** for helping you to understand and learn the mathematics covered by the Basic Skills Review? *Options*: Not applicable – I rarely used the video / worked resources, Of little importance, Moderately important, Extremely important
Improve understanding, learning and solving question I believe that by using the **video solutions** or the **worked solutions** in MATH141, I can now better understand and learn the course material. *Options*: Did not use them, False, True, Don't know
I believe that by using the **video solutions** or the **worked solutions** in MATH141, I can solve more mathematics problems than before. *Options*: Did not use them, False, True, Don't know

Continued over page …

Table 5.3 (*Continued*) Survey Questions – Part 1

Working independently
Do you think the video solutions helped you to work independently of other students and tutors?
Options: No, I did not use the video solutions, A little bit more independently, Yes

5. Several questions were related to the comparison of video solutions with worked/print solutions, the amount of voice-over video solutions, the role of the hand of the solver, the sufficiency of the picture quality (Table 5.4).

Table 5.4 Survey Questions – Part 2

Amount of voice and preference of listening to voice
Was the amount of voice enough for the **video solutions**?
Options: Too little, Just right, Too much

Do you like to listen to the voice for the **video solutions** when following the solutions?
Options: I prefer to turn off the voice, Just for some questions that I couldn't understand, Yes

Quality of the video resources
How was the picture quality of the **video solutions**?
Options: too poor to use, poor, good, more than adequate

Use of the resources
Does the on-screen hand in some of the **video solutions** help you to understand and learn mathematics?
Options: No, I didn't notice it, Yes

Overall, did the **video solutions** help you understand and learn mathematics?
Options: Not at all, Slightly, Yes

How did you find the use of the **video solutions** or the **worked solutions**?
Options: It was time consuming for me to use them, I found it difficult to use them, I found it easy to use them.

CD-ROM given to students
In the future, if a CD-ROM of the **video solutions** was available for all the topics, would you
Options: Not use it and only go to tutorials, Use it in addition to going to tutorials, Use it instead of tutorials, Don't know

In the future, if a CD-ROM of the **worked solutions** was available for all the topics, would you
Options: Not use it and only go to tutorials, Use it in addition to going to tutorials, Use it instead of tutorials, Don't know

Access to more video/worked solutions
Would you like to have access to more **video solutions** or **worked solutions** for those parts of MATH141 presently not covered?
Options: No, Yes, Don't Know

Preference of video or worked solutions
If you just access to the **video solutions** or the **worked solutions** which one do you prefer?
Options: Neither is required, Video solutions, Worked solutions, Either is fine

As video resources were developed in two formats (avi, mp4) students were asked 'To use video solutions I have been using: PC (windows computer), Macintosh (Apple computer), Other'. To assess the impact on learning they were also asked to provide their scores in Basic Skills Test 1, Basic Skills Test 2 and the Mid-Session Test. Students were then asked open-ended questions about how to improve video or worked/print resources to enhance their learning and understanding of mathematics and which, if any, topics needed more video solutions (Table 5.5).

Table 5.5 Open-ended Survey Questions

How have the **video solutions** or the **worked solutions** helped you to understand and learn mathematics?
How best can the **video solutions** resources be improved to help your understanding and learning of mathematics?
How best can the **worked solutions** resources be improved to help your understanding and learning of mathematics?
Which topics in MATH141 require more **video solutions** or **worked solutions** for practice?
How best can the MATH141 be improved?

5.3.2.3 Outcomes

The primary purpose of the evaluation in this section is:

- to assess the quality of the learning resources,
- to examine the impact of video and worked/print solutions on student understanding and learning,
- to pinpoint the nature of the learning or understanding that was taking place through using the resources and
- to identify the characteristics of those using the resources compared to those who did not.

Ninety-two students, from a class of 216, took part in the survey. A determination of whether or not males and females preferred different resources was not considered appropriate as the respondents were predominantly male. The respondents included 82 male students (89.1%) and nine female students (9.8%), with one student not providing gender information.

Quality of Video Resources

Questions included in the mid-session survey allowed an assessment of design aspects of the videos to determine whether changes needed to be made to future resources. Responses to the prompts were:

- 'Was the amount of voice enough for the video solutions?', out of 92 students, 61% responded 'just right' (n = 56), 13% of students answered 'too little' (n = 12) and just 2% of students considered it as 'too much' (n = 2), while 24% of students did not respond to this question (n = 22).
- 'Do you like to listen to the voice for the video solutions when following the solutions?', 34% of students answered 'Yes' (n = 31), the same percentage 34% responded 'just for some questions that I couldn't understand' (n = 31), 12% preferred to 'turn off of the voice' (n = 11) and 21% of students did not respond (n = 19).
- 'Does the on-screen hand in some of the video solutions help you to understand and learn mathematics better?', 57% of students respond 'Yes' (n = 52), 13% replied 'I didn't notice it' (n = 12), 11% answered 'No' (n = 10) and 20% students did not respond (n = 18).
- 'How was picture quality of the video solutions?', 16% of students answered 'more than adequate' (n = 15), 57% of students responded 'good' (n = 53), 7% of them said that the quality was 'poor' (n = 6), just one student answered 'too poor to use', and 20% students did not respond (n = 18).
- 'How did you find the use of the video solutions or the worked solutions?', 59% of students answered 'I found it easy to use them' (n = 54), 7% of them responded 'I found it difficult to use them' (n = 6), 14% of students answered 'It was time consuming for me to use them' (n = 13) and 21% students did not respond (n = 19).

As mentioned earlier, other methods could have been used to produce graphics or images of mathematics symbols that could be displayed on a webpage. For example, images created in MathML or LaTeX can be exported as JPEG images and then displayed in HTML format, however this approach was not used here. Although there is currently no empirical evidence, it was believed that one of the strengths of the website was the similar “look” of the mathematical notation in the questions, in the answers and in the worked solutions. In this way students could easily and intuitively connect the notation in all parts of the question and its solution. From a technological point of view, the method that was used is a way to efficiently and effectively represent mathematics notation on the World Wide Web.

Video solutions were produced in two formats so that students could use either a Windows or an Apple computer. To ascertain demand for the two versions, students were asked, ‘To use video solutions I have been using: PC (Windows computer), Macintosh (Apple computer), Other’. Out of 92 students 71% of students answered ‘PC (Windows computer)’ (n = 65), 4% of students responded ‘Macintosh (Apple computer)’ (n = 4), 1% student answered ‘Other’ (n = 1) and 24% students did not answer the question (n = 22).

Impact of Resources on Students Learning

The purpose of the video and worked solutions was to help students improve their understanding of the mathematics. In the mid-session survey, 63% of students believe that ‘by using the video solutions or the worked solutions in MATH141, I can now better understand and learn the course material’ (n = 58). In addition, 72% believe that ‘by using the video solutions or the worked solutions in MATH141, I can solve more mathematics problems than before’ (n = 66). The results are shown in Table 5.6.

Table 5.6 Impact of Video Resources on Learning and Solving Problems

N= 92	**True** %	**False** %	**Don’t know** %	**Did not use them** %	**No Response** %
video/ worked solutions - better understand and learn the course	63.0	1.1	14.1	4.3	17.4
video/ worked solutions - can solve more mathematics problems than before	71.7	0	6.5	4.3	17.4

In response to ‘Overall, did the video solutions help you understand and learn mathematics?’, 75% of students found them useful (n = 69), 4% answered ‘Not at all’ (n

= 4) and 21% did not answer (n = 19). Two separate questions asking students how important the video or worked solutions were for helping them to understand and learn the mathematics covered by the Basic Skills Review allowed a comparison of student preferences for the video versus the printed or worked solutions. Results revealed that the worked (printed) solutions are considered extremely or moderately important by 68% of students compared to 59% indicating the video resources (Table 5.7). It is likely that printed solutions, when adequate, are preferred, as these are quicker to access and use than the video resources. Audio is probably more useful in points in the solution where common mistakes are noted or further explanation required. As one student commented:

> Worked solutions are more helpful as they are not time consuming and I can see exactly what has been done.

For students who have problems, however, the videos are more appropriate. As one student commented:

> I have found all worked solutions to be adequate however anything that I am unsure of can not be shown on paper.

Table 5.7 Usefulness of Video and Worked Solutions in Helping Students to Understand and Learn Mathematics

N= 92	Moderately important %	Extremely important %	Total important %	Little Important %	Not Applicable-rarely used %	No response %
Video solutions	46.7	12.0	58.7	6.5	19.6	15.2
Worked solutions	29.3	39.1	68.4	8.7	8.7	14.1

One of the aims of the resources was to allow students to engage in self-paced learning and to establish practices that could allow students to learn independently (Chapter 2). In response to ‘Do you think the video solutions helped you to work independently of other students and tutors?’ 30% responded ‘Yes’ (n = 28), 38% could work ‘a little bit more independently’ (n = 35), 7% answered ‘I did not use the video solutions’ (n = 6); 5% answered ‘No’ (n = 5) and 20% did not respond (n = 18).

Discussion on learning outcomes (Chapter 2) suggested that the terms *learning* and *understanding* may cover a wide variety of different types of learning. Hence, students were asked an open-ended question, 'How have the video solutions or the worked solutions helped you to understand and learn mathematics?'. Sixty-four per cent of 92 students responded with comments (n = 59). Often a student response was indicative of more than one advantage from using the resources. Students' responses suggested that the resources aided in the development of a variety of different types of learning or provided other advantages.

Algorithmic learning

Statements made by 16% of students suggested that students learned a process for doing the mathematics (n = 15). Evidence of algorithmic learning was evidenced by statements such as

> Allowed us to see the step by step process.
>
> Simply showed us the required steps to follow in an unknown problem.

Sometimes, comments hinted at something more than just understanding a step by step process. These suggested improving thinking, better transfer of learning or improving the mastering of the algorithmic process:

> Step by step process thinking process expressed.
>
> Provided me with useful steps in which to solve various problems.
>
> Worked solutions are very useful when figuring out a question, or a similar question to a problem I have.
>
> Worked solutions are good as they give a step by step produce to solve problems where as the video solutions are used if unsure of any of the steps.

Figuring out, helping, and correcting mistakes

Thirteen per cent of students (n = 12) made comments that suggested they knew the algorithm, the steps involved, but that at any step in the process they could get stuck or make a mistake. At that point the video solutions were of value. Comments included:

> I could see where I was going wrong with my working when I got the wrong answers for certain questions.

> Showed me where I went wrong if I stuff up.
>
> It has helped me compare and find little mistakes in my own working out.
>
> Often a problem involves a long procedure in order to solve the video and worked solutions allowed me to discover what 'step' I am having difficulty with or if it was simply a 'silly/careless' mistake I had made.
>
> When I am stuck with just a single step the worked solutions are good but when I am having trouble with a concept the video solutions are good.

Thinking and understanding

Statements made by 23% of students (n = 21) made mention of better understanding. Statements include:

> Allows me to understand the thinking process needed to solve a given problem.
>
> They have helped me understand principles and the background information behind the problem.
>
> It has given me a better understanding by having clear working and good explanation.
>
> It is always better to see someone complete the problem step by step. Then the addition of audio helps to understand the reason behind each step.
>
> It gives me different kind of math problems to think of and it let me challenge myself to get the answer before rereading it by looking at the video solution.
>
> Allows understanding of principles often over-simplified or 'shortcutted' by lecturers and tutors.

Sometimes it was not clear if this meant an understanding or if indeed it was another way of describing algorithmic learning. Comments included:

> Understanding the steps involved.
>
> Explain solution step by step, so I am clearly understand inside.
>
> Presented problems that I could not work out or understand before going over the worked solutions.
>
> The process is good. It provokes your thought process to understand the method to solving the problem.

Other advantages

Other advantages related to a range of learning outcomes:

Practice: Just gave me some more questions to answer.

Memory: Good for memory.

Checking answers: Can check your answers.

Style and layout: Just the style and setting out of problems help.

Alternative materials: Allowed me to use additional material.

Going at your own pace: Each of the solution methods meant I could go through each step of the problems at my own pace.

Repetition: As many times as I needed them, ready to help repeatedly.

Additional details: Understand questions in greater details; they helped fill in the blanks that the text book left out.

Explained every step during the work. I was able to clarify certain rules that I didn't know properly.

Prompting recall: Just going through the systematic steps helps. Showing where certain bits or knowledge are required for each question that I might not remember or know how.

Independent learning: Allowing independent learning.

Advance organising: Gives me an idea of the type of questions that we need to know.

When students were surveyed after the Mid-Session Test, they were asked if they had used video resources or not, and what their marks were for the Basic Skills Tests and the Mid-Session Test. This enabled a comparison of marks in all three assessments to be made comparing those students who had used the resources with those who had not. As the analysis was done on students recalled marks there are a greater number of missing marks for the earliest Basic Skills Test 1 where only 76 students reported their marks. For Basic Skills Test 2 there were 81 students reported marks and for the Mid-Session Test 83. As the data were collected after the Mid-Session Test, there were no marks available for the Final exam. These survey data were collected anonymously and there was no way of determining which student used or did not use resources.

Comparison of Basic Skills Tests 1

Basic Skills Test 1 was conducted prior to the video resources becoming available to students. A Levene's test revealed no statistically significant difference in variance between students who later used the video resources and those who did not ($F = 1.98$, $p = 0.16$). An independent t-test revealed a statistically significant difference in mean marks out of 20 for Basic Skills Test 1 ($t_{74} = 2.18$, $p = 0.03$), with those using the video resources having a lower mean mark of 9.85 (s.d. = 3.59, n = 65) compared to a mean of 12.27 (s.d. = 2.10, n = 11) for those did not use the resources. This suggests a self-selection effect; students who had lower average marks chose to use the resources while those who were on average better students did not.

Comparison of Basic Skills Test 2

In Basic Skills Test 2 in week four, there was no significant difference in the variance of marks ($F = 0.05$, $p = 0.82$) or in the mean of the marks ($t_{79} = -0.74$, $p = 0.46$) as tested by an independent t-test which compared the group of students using video resources, who averaged 12.26 (s.d. = 3.51, n = 69), with those not using video resources, who averaged 13.08 (s.d. = 3.66, n = 12).

Comparison of the Mid-Session Test

At the Mid-Session Test in week eight there was no significant difference in the variance of marks ($F = 0.67$, $p = 0.42$) or in the mean of the marks ($t_{81} = -0.73$, $p = 0.47$) as tested by an independent t-test comparing the group of students who used video resources and averaged 16.56 (s.d. = 3.53, n = 70) with those who did not use video resources and averaged 17.31 (s.d. = 2.78, n = 13).

Comparison of the Change Scores

The change score measures the differences between scores BST1 and BST2 for those who used the resources and those who did not. A comparison of the change scores was conducted.

A Levene's test for the equality of variances revealed no significant differences in variance between those who had used the resources and those who had not ($F = 0.03$, $p = 0.87$). An independent t-test analysing the change in marks between the two tests found a significant difference ($t_{72} = 2.43$, $p = 0.02$) between those who used video resources, mean change in mark (BST2-BST1) of 2.25, (s.d. = 2.97, n = 64) compared to the non-users whose mean change marks was negative, – 0.20, (s.d. = 2.97, n = 10).

The mean change of 2.3 represents a 23% increase over their original marks of 9.9 out of 20 for BST1. The students who did not use the resources had a slight, 2% reduction in marks compared to an original mean mark of 13.1 out of 20 for BST1. Most significant are changes from a fail grade to a pass conceded or pass grade. Students who fail introductory mathematics subjects are candidates for dropping out of university. Thus, by the end of the fourth week it appeared that the use of the video resources allowed the weaker students to catch up with the stronger students. This is an encouraging finding as the students most in need of useful learning resources were the weaker students who were at risk of failing the subject.

The change in scores which is the subject of the next analysis is defined as the differences between scores of Basic Skills Test 1 and the Mid-Session Test. A Levene's test for the equality of variances of the change in scores revealed no significant differences in variance between those who had used the resources and those who had not ($F = 0.94$, $p = 0.34$). An independent t-test analysing the change in scores between the two tests found a significant difference ($t_{73} = 2.00$, $p = 0.05$) between those who used video resources, mean change in scores (MST – BST1) of 6.58, (s.d. = 3.51, n= 64) compared to the non-users whose mean change scores was 4.36, (s.d. = 2.50, n = 11).

A Pearson correlation showed that for those students who used the video resources there was a significant negative correlation (– 0.45) between marks out of 20 for Basic Skills Test 1 and the change in score from BST1 to BST2 ($p < 0.001$, $n = 64$). Students with a lower score on BST1 tended to have a greater improvement in their BST2 score than those who had better score in BST1 (Figure 5.3). One student who had a BST1 score of 19 and a BST2 score of 11 appeared quite different from the rest of the group. In case this student's score was an error in recall, the isolated point was removed and a second correlation was performed. However, there was still a significant negative relationship ($r = -0.39$, $p = 0.001$, $n = 73$).

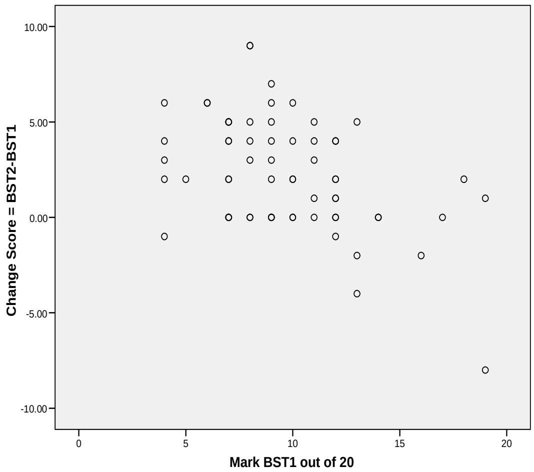


Figure 5.3 Scatterplot Showing the Relationship between BST1 Marks and Change Score for Students Who Used the Video Resources

In contrast, for students who did not use the video resources there was no significant relationship between differences between marks out of 20 for Basic Skills Test 1 and the change score from BST1 to BST2 ($r = 0.02$, $p = 0.95$, $n = 10$).

5.3.2.4 Implications

One of the issues that emerges when new resources are introduced is whether or not the old resources continue to be valued and used or whether one resource is simply replaced by another. A small proportion of students, 11%, found the video resources an adequate replacement for tutorials, when asked ‘In the future, if a CD-ROM of the video/worked solutions was available for all the topics, would you: Not use it and only go to tutorials, Use it in addition to going to tutorials, Use it instead of tutorials, and Don’t know’. However, the majority of students, 65%, chose it as a support resource in addition to tutorials. The results are shown in Table 5.8.

Table 5.8 If a CD-ROM of the Video or Worked Solutions was Available for All the Mathematics Topics

N = 92	Use it instead of tutorials %	Use it in addition to going to tutorials %	Not use it and only go to tutorials %	Don’t know %	No response %
CD-ROM of the video solutions	10.9	65.2	0	6.5	17.4
CD-ROM of the worked solutions	10.9	63.0	0	8.7	17.4

The resources produced had been useful to students in terms of helping them learn and understand. Students who used the resources had improved their marks compared to those who did not use the resources. Responses to the question ‘Would you like to have access to more video solutions or worked solutions for those parts of MATH141 presently not covered?’, indicated that 74% of the respondents wanted more resources (n = 68). Only 2% of students did not want more resources, and 19% did not answer the question. Analysis of student responses to the question ‘Which topics in MATH141 require more video solutions or worked solutions for practice?’ indicated that the topics ‘vectors’, ‘matrices’, ‘differentiation’ and ‘trigonometry’ were the main areas where additional video resources were required (Table 5.9). As this was an open response, it may be that some topics did not come to mind. Notably, 16% of respondents indicated that they wanted resources for all topics. These findings led to the creation of additional video resources for incoming students in 2007.

Table 5.9 Require More Video Solutions or Worked Solutions – Week 8

N = 92	Number of students
Vectors	21
Matrices	16
Differentiation	15
All topics *	14
Trigonometry	9
Integration	5
Polar Coordinates	5
Implicit differentiation	4
Logarithms	3
Geometry	3
Functions	2
Calculus	1
Inverse functions	1
Inverse trigonometry functions	1
Hyperbolic functions	1
Limits	1
Parametric differentiation	1
Determinants	1
Polar curves	1
Did not use them	1

* One response indicated that ‘more simple things should also be covered as this provides the foundation for understanding’ while two others indicated ‘all except for the more basic stuff’

A one-way ANOVA was used to see if there were differences in the mean marks between the three groups: those who wanted video resources for all topics, those who wanted them for selected topics and those who did not list any topics (Table 5.10). There was no significant difference in mean marks between the groups for Basic Skills

Test 1 ($F_{2, 73}$ = 1.58, p = 0.21), Basic Skills Test 2 ($F_{2, 78}$ = 0.55, p = 0.58) and the Mid-Session Test ($F_{2, 80}$ = 1.54, p = 0.22).

Table 5.10 ANOVA Comparing Performance of Those Who Requested Videos for All, Selected Videos and No Videos

		Sum of Squares	df	Mean Square	F	Sig.
Mark BST1 out of 20	Between Groups	38.14	2	19.07	1.58	0.21
	Within Groups	883.90	73	12.11		
	Total	922.04	75			
Mark BST2 out of 20	Between Groups	13.87	2	6.94	0.55	0.58
	Within Groups	979.27	78	12.56		
	Total	993.14	80			
Mark Mid-Session Test out of 25	Between Groups	35.53	2	17.76	1.54	0.22
	Within Groups	922.69	80	11.53		
	Total	958.22	82			

An examination of the means reveals that for all three responses the average mark of those requesting video resources for all topics was lower, although not significantly so, than that of students requesting some topics, and this, in turn, was lower than the average for those requesting no topics. Those who request some topics and no topics seem to be more similar in terms of means than those requesting all topics (Table 5.11).

Table 5.11 Requesting Video Solutions

		N	Mean	S.D.	S. Error
Mark BST1 out of 20	No topics	32	10.66	3.54	0.61
	Specified topic	35	10.26	3.43	0.58
	All	9	8.33	3.43	1.14
	Total	76	10.20	3.51	0.40
Mark BST2 out of 20	No topics	34	12.59	3.69	0.63
	Specified topic	38	12.47	3.58	0.58
	All	9	11.22	2.68	0.89
	Total	81	12.38	3.52	0.39
Mark Mid-Session Test out of 25	No topics	35	17.31	3.24	0.55
	Specified topic	39	16.44	3.63	0.58
	All	9	15.22	2.82	0.94
	Total	83	16.67	3.42	0.38

Analysis of the open-ended question, ‘How best can the worked solutions resources be improved to help your understanding and learning of mathematics?’ provided several suggestions.

More examples

More examples/topics, a larger range of questions and answers.

Questions from past exams.

More of them, medium and hard examples.

All topics.

Greater details

More in-depth coverage of complicated problems with reasoning for each step. By including why they did each step in solving the problem. In some sections more details.

Include all steps.

Perhaps vary the amount of detail in the steps - allows the user to choose according to their skill level.

Show every line of working even little sections which are obvious.

Alternative approaches

By providing more possible solutions for each problem, sometimes we can get the correct answers from different ways and techniques and it's more useful to understand all the possible solutions.

Quality

Maybe a little neater but other than that they are fine.

The video quality for some worked solutions (that don't involve the 'hand') could be greatly improved.

Embedding

Link them to the resources within the text. That may we can refer to chapters of the book to see what rules were used in the solutions.

Structuring

There can be worked solutions for material which is fairly easy then process to complex solutions.

As the development of videos was an ongoing process throughout the session, the initial concept was to distribute these video resources through WebCT. Approximately 6% of students suggested improvements related to making it easier to save the videos from the website.

> I can't save them! Need to be able to save. I don't have a downloading tool and no access to internet outside UOW websites to download a tool. Hence only used video solutions once and not again. If I could save them to PC, I would use them all the time. Make a right click- save as option so you can save them to your computer easily!
>
> They are very big, and take a long time to download on a slow connection, unless you're on a fast internet connection. Make file size smaller, a link to download the file! Quicker to load on a slower computer.
>
> [Improve the videos] by providing every student with a CD. This would help students with low speed internet connections.

It is now common for students to download files onto a USB-drive, however a secondary aim was to distribute the resources via CD-ROM or DVD. The student comments also suggest that it is important to develop alternative distribution methods such as CD-ROMs. This could also be extended to include DVD and iPod. A simple trial revealed that the video resources could be saved in a format suitable for iPods, but this has so far not been pursued.

Suggestions for how to improve the videos included the following:

More examples

> Equivalent difficulty to the exams, worked solutions to all tests,

Update more frequently

> It's ok how it is as long as it's updated.

Provide more similar examples

> It's better to make some more similar examples available to think of.

More on principles

> The video solution can best be improved they explained the principles and theory behind the lecture material more thoroughly as there is inadequate in lectures to process material.

More explanation

> The audio should be improved as it makes statements about what it is doing in each step but needs more in depth justifications.

Modelling

> Show how other people are supposed to think.

Varied levels of explanation

> Perhaps vary the amount of detail in the steps - allows the user to choose according to their skill level.
>
> Not to use assumed knowledge as a step.
>
> Step by step break down and analysing of the question.

More

> More content.
>
> More on the approaches.

The suggestions that arose throughout the evaluation caused raised the question of what precisely it is that students gain from using the resources. In 2007, the evaluation sought to elaborate what it was that students gained from the videos.

Video solutions are more expensive to produce than worked solutions. One of the questions asked was whether or not the additional cost was warranted. Analysis of the student responses to the question, 'If you just access to the video solutions or the worked solutions which one do you prefer?', revealed a mix of preferences with 19% of students preferring video solutions (n = 17), 26% of students answering that either is fine (n = 24), 32% preferring worked solutions (n = 29), 3.3% of them responding that neither is required (n = 3) and 21% not responding (n = 19). The development of the resources was to target students that were most likely to fail. With failure rates for this subject running at 28-30%, the fact that 19% preferred the video and this implied an additional level of explanation, it was decided to expand the set of resources available to students.

Another consideration in designing subjects and assessments is the notion that the time for the average student to complete a single session 6 credit point subject is 12 hours per week. Five hours of the twelve are completed in lecture and tutorial classes. Previous data have suggested that the majority of students do not commit the time expected in the MATH141 equivalent subject (Porter 2004), suggesting that a requirement that engages students in more work is reasonable. Hence understanding how much time students used on resources is of interest. Seventy per cent of students responding to the question 'On average how much time did you spend using the video solutions or the worked solutions either through the website or from CD-ROM each week?' answered between none and 2 hours with 12% using the resources between 3-5 hours, with 4% reporting between 6 and 8 hours work per week using the resources. For the vast majority of students, the time commitment is not high. Weaker students do need to spend additional time or use time more effectively to successfully complete the subject.

Examination of the need for video resources or the success of those resources is likely to relate to students' perceptions of other aspects of the subject. Other comments to the question 'How best can the MATH141 be improved?', suggested the need for improvements in the lectures, tutorials and resources available for the subject. More specifically students commented:

Lectures and lecture resources

> Lecture resources should be put up on WebCT from all the lecturers. At the moment the vectors slides are not on WebCT so it is hard to summarise and go over them at home because they are different from the notes in the book.
>
> The problems in vectors section in-depth examples and worked solutions needed.
>
> By recovering the section on matrices and showing us everything.
>
> Teaching methods more similar to HSC 3U Maths e.g. the way composition of functions and differentiation is taught.
>
> Make it a little more exciting.
>
> More extensive coverage of main topics.
>
> More trigonometry.
>
> Complete worked examples on the overheads, don't leave them a few lines short.
>
> Work more and longer on questions.
>
> More revision.

Online resources and other resources

> More online stuff for all topics.
>
> Maybe an online Q and A chat session with tutors.
> Perhaps the vectors lecture notes could be put online more in advance.
>
> Give worked solutions to all tests.
>
> The geometry part has few examples for us. This makes us to understand the lecturer harder.
> Better books, perhaps a book on matrix, a separate booklet.
>
> More questions of similar type but worked differently.
>
> Provide easier access to lecture notes such as slideshow PDF files NOT overheads.
>
> More awareness quizzes in order to give us an indication of where we are standing.

Tutorials

> Fewer students in tutorials.
>
> Longer tut[orials].
>
> Do more questions in tutorials as a group, not individually on whiteboards.
> I think we get better results if we turn tutorial classes more like PASS classes.
>
> In tutorials write down on paper the work you are doing so that you can look over how to do problems instead of just rubbing it out off a whiteboard or by having tutorial classes in a high school type environment where the tutor explains on the whiteboard to the entire class how to do some of the questioned with which we have difficulty.
>
> Provide more varied time and locations for the PASS tutorials.

Communication

> Better communication between lecturers, tutors and coordinators. In one assignment we were asked a question from a sub-topic that the lecturer had told us we didn't need to know.

5.3.3 Evaluation - End of Session Change Evaluation

The video resources developed on this pilot study and made available in the Autumn Session 2006 covered approximately 15% of the subject material. In particular, it only covered 30% of the material taught in the ‘revision’ component of the subject. At the end of session, students completed a change evaluation meeting the requirements of the QUALITY101 working party (Chapter 3). To this standard evaluation, several questions were added relating to the use and worth of the video resources.

5.3.3.1 Aims

Students were given a survey at the end of session in week 12 in Autumn Session 2006 (Appendix 12). The primary purpose of this evaluation was to:

- evaluate the effectiveness of the videos compared to the rest of the learning resources available to students, (lectures, tutorials, etc.) in terms of helping them learn and understand mathematics; and
- obtain students’ feedback in regard to the subject as a whole, in order to assist in the future development of MATH141.

Secondary considerations were to confirm earlier findings as to:

- How best to improve/enhance quality of learning and teaching of mathematics?
- Which additional learning resources are required by first year students?

5.3.3.2 Method

The change evaluation was administered in week 12 of the session. For data collection the following steps were taken:

1. Ethics approval was obtained from the University of Wollongong Ethics Committee (no. HE06/21).
2. Students were invited and encouraged to participate in the survey with instructions indicating that the purpose of survey was to recognise the impact of learning resources on students’ learning and grade. Students were informed in the Participant Information Sheet (Appendix 6) that

The purpose of this research is to examine the impact of learning resources provided to you and to devise ways of:

- developing your knowledge and skills in a manner appropriate for your achievement of the subject objectives and
- supporting you in developing strategies that will enable you to learn more effectively.

3. Students answered questions including the usefulness of learning resources, topics about which students feel competent and the need for more video solutions (Table 5.12).

Table 5.12 Survey Questions – End of Autumn Session 2006

Usefulness of Learning Resources How useful are the existing resources in helping you understand in this subject? *Resources listed:* Lectures, Lecture notes via WebCT, Fill in lecture notes, Textbook Mathematics 1C, WebCT Forum, Tutorial classes, Tutor in tutorial classes, Tutorial tasks, Tutorial solutions, Assignments, PASS program sessions, Basic Skills Tests, Mid-Session Test, Video Resources, Other work done in your own time *Options:* Rarely used this resource, Little use, Moderately useful, and Extremely useful
Identifying topics where students feel competent or not How confident are you that you can solve problems involving: *The topics:* Fundamentals (Basic Skills), Differentiation, Polar Coordinates, Integration, Matrices and Determinants, Vectors Geometry *Options*: Not at all, Might have a Little difficulty, Moderately confident, Could do this
Identify topics which need more video solutions Circle the topics where you need more video solutions: *The topics:* Indices, Surds, Logarithms, Factorisation, Algebraic Fractions, Functions, Quadratic Equations, Geometry, Trigonometry, Limits, Elementary Differentiation, Hyperbolic functions, One-to-one and inverse functions, Inverse Trigonometric functions, Inverse Hyperbolic functions, Derivative of an inverse functions, Logarithmic Differentiation, Implicit Differentiation, Parametric Differentiation, Polar Coordinates, Polar Curves, Methods of Integration, Index and Sigma Notation, Application of Matrices to systems of Equation, Determinants, The Eignvalue Problem, Dot product of Two Vectors, Cross Product of Two Vectors, Planes
Relevance of the subject Compared to when I started MATH141, I now view mathematics *Options*: as less relevant to my life and/or anticipated profession, about the same relevance as when I commenced, as more relevant to my life and/or anticipated profession

An open-ended question also asked if there were any topics that students would like to see in videos: 'Are there any mathematics topics that you would like to see in videos?'.

Questions about completing the subject, time spent on MATH141 and attendance at PASS programs are presented in Table 5.13.

The change evaluation questionnaire, as determined by the QUALITY101 working party, was modified to allow comparability across engineering, mathematics and computing subjects. Rather than asking for specific marks, students were asked 'Given the work I have done and feedback obtained, the grade I expect to get in this subject is: Fail (<45%), Pass conceded (45-49%), Pass (50-64%), Credit (65-74%), Distinction (75-84%), High distinction (≥85%)'. This was supplemented by one question asking students for their mark in the Mid-Session Test in this subject.

Table 5.13 Questions on Work Practices

Do you consider that you have completed the lecture component by *Options:* attending virtually all lectures; attending virtually all the lectures and doing the exercises as they are required for assessment; attending virtually all lectures and doing the exercises in the textbooks; Other
Including lectures and tutorials and work outside class, on average per week how much time did you spend for the first twelve weeks of session working on MATH141? *Options:* 0-2 hours per week, 3-5 hours per week, 6-8 hours per week, 9-11 hours per week, 12-14 hours per week, More than 14 hours per week
How many PASS program sessions did you attend? *Options:* 0, 1-3, 4-6, 7-9, 10-13, 14

Similar to 2005, an open-ended question was used to assess the academic integrity of the subject: 'Do you consider that the assessment system is fair and that students basically earn the marks they get or is it rife with cheating or ... ?'. Students were then asked an open-ended question to identify different ways to enhance the subject 'How best can the MATH141 subject be improved?'. Finally as differences had been found between international and domestic students and males and females in the type of resources they preferred, students were asked questions about their language: 'Is English your first language?' with options: 'Yes' and 'No'; and gender: 'Select your gender' with options: 'Female' and 'Male'.

5.3.3.3 Outcomes

The results of this survey have been used to determine which resources students identify as useful for helping them to learn and understand the subject, or for further development for use by incoming students in Autumn Session 2007. Identifying primary resources that are not considered useful is one way of identifying where there is greatest scope to make improvements.

Eighty-three students out of 216 participated in the change evaluation survey with 80% male (n = 66), 15% female (n = 12) and 5% who did not indicate (n = 5). Seventy-six per cent of students had English as their first language (n = 63), and 19% had English as their second language (n = 16) and 5% did not answer (n = 4).

Not surprisingly, the students who completed the survey were students who expected to perform well. As can be seen in Table 5.14, the distribution of anticipated grades was much higher than the actual grades obtained. This is a bias that poses a difficulty when researching how to improve mathematics education as students who fail or opt out are often not participants in processes that could improve the subjects in ways from which they could benefit. Students in this sample also tended to overestimate their performance.

Table 5.14 Distribution (Per cent) of Final Grades and Grades Anticipated by Survey Respondents

Year	N	Fail	Pass Conceded & Pass	Credit	Distinction	High Distinction
2006	209	28.7	50.7	13.4	4.3	2.9
Sample*	83	3.6	43.3	39.8	2.4	7.2

* 3.6% did not respond

Usefulness of Learning Resources

To assist students in their learning and understanding of MATH141, learning resources such as lectures, lecture notes via WebCT, tutorial classes, the PASS program and video resources were presented during the session. In response to the question ‘How useful are the existing resources in helping you understand in this subject?’, students’ responses to the primary learning resources are presented in Table 5.15. Those for the support learning resources, WebCT, the PASS program and the video learning resources are in Table 5.16. The primary resources are those that form the package of resources with which students have been provided for many years. The support resources represent resources that would not usually have been supplied, or are subject to others agreeing to supply them, such as the PASS program. They represent additional resources provided to students.

Table 5.15 Change Evaluation: Usefulness of Primary Learning Resources

N=83	Responding N	Moderately useful %	Extremely useful %	Total N	Total %
Lectures 1	81	49.4	44.4	76	93.8
Tutorial tasks	81	59.3	28.4	71	87.7
Tutorial classes	80	43.8	40.0	67	83.8
Tutor in tutorial classes	80	41.3	41.3	66	82.5
Assessment: Assignments	81	56.8	24.7	66	81.5
Assessment: Mid-Session Test	81	56.8	24.7	66	81.5
Lectures 2	81	49.4	28.4	63	77.8
Tutorial solutions	81	34.6	42.0	62	76.5
Other work done in your own time	81	42.1	33.3	61	75.3
Textbook Mathematics 1C	81	42.0	32.1	60	74.1
First lecture notes via WebCT	80	35.0	31.3	53	66.3
Second lecture notes via WebCT	80	40.0	25.0	52	65.0
Fill in lecture notes 1	80	37.5	27.5	52	65.0
Assessment: Basic Skills Tests	81	42.1	22.2	52	64.2
Lectures 3	80	37.5	16.3	43	53.8
Third lecture notes via WebCT	78	30.8	16.6	37	47.4

*Respondents who did not answer these questions have been omitted from the analysis

Table 5.16 Change Evaluation: Usefulness of Support Learning Resources

N=83	Responding N	Moderately useful %	Extremely useful %	Total N	Total %
PASS program sessions	78	24.4	52.6	60	76.9
Video Resources	79	31.6	25.3	45	57.1
WebCT forum	80	16.3	3.8	16	20.0

*Respondents who did not answer these questions have been omitted from the analysis

When the QUALITY101 working party introduced the change evaluation rankings of resources, these were interpreted to involve a mix of educational logic and numerical outcomes. The resources that ranked lowest are identified as areas providing the greatest scope for improvement (Porter 2005b). Based on the rankings in this instance, the notes and lectures provided by the third lecturer most warrant improvement. Examination of the top-ranked resource, lectures by the first lecturer were ranked so highly that energy spent on improving those, rather than improving other aspects of the subject, would be misplaced. Rather than focusing on lecturing, this lecturer could more profitably spend more effort in other areas, such as improving the lecture notes or assessment tasks. This is a characteristic pattern for some of the best lecturers (Porter 2005c).

Although the lecturer of MATH141 does not describe the Basic Skills Tests as a primary learning resource, he sees it as a bonus for the calculation of marks. The Basic Skills Tests do not, however, contribute as effectively to student learning as the assignments do. In terms of absolutes, the QUALITY101 expectation is that the score for each primary resource is over 90% (Porter 2006a).

The transitional video learning resources developed as a trial were found useful by 57% of respondents, a comparable proportion to the third lecturer (54%) and higher than a set of lecture notes for 'vector' topics (47%). The video resources are not as popular as the PASS tutorials, however the PASS tutorials have an ongoing cost for tutors. There is also scope for improving the WebCT forum but this involves additional input from the lecturers.

Identifying Topics for Competency and Developing Video Solutions

Responses to the question 'How confident are you that you can solve problems involving fundamentals, differentiation, polar coordinates, integration, matrices and determinants, and vectors geometry?' (Table 5.17) revealed a lower confidence with completing 'vectors' then 'polar co-ordinates'. Over 80% of respondents felt confident in only two of these topics: 'fundamentals' and 'differentiation'.

Table 5.17 Identifying Topics Where Students Feel Competent or Not

Identifying topics where you feel competent or not N =83	**Responding**	**Moderately confident**		**Could do this**		**Total**	
	N	**N**	**%**	**N**	**%**	**N**	**%**
1. Fundamentals (Basic Skills)	81	37	45.7	33	40.7	70	86.4
2. Differentiation	81	40	49.4	27	33.3	67	82.7
3. Polar Coordinates	81	36	44.4	13	16.1	49	60.5
4. Integration	81	32	39.5	22	27.2	54	66.7
5. Matrices and Determinants	81	38	46.9	15	18.5	53	65.4
6. Vectors Geometry	81	27	33.3	7	8.6	34	41.9

* 2.4% of respondents who did not answer these questions have been omitted from the analysis

For a finer examination of topics that required resources, students were asked to 'Circle the topics where you need more video solutions' (Table 5.18). The need for resources ranged from 12% to 49% of students, again reinforcing the need for resources.

Table 5.18 Rank Ordering of Topics Needing More Video Resources

Identifying topics to develop more video solutions	**Yes**	
	N	**%**
1. Planes	41	49.4
2. Eignvalue Problem	36	47.0
3. Implicit Differentiation	33	39.8
4. Inverse Trigonometric functions	30	36.1
5. Application of Matrices to systems of Equation	28	33.7
6. Dot product of Two Vectors	28	33.7
7. Cross Product of Two Vectors	28	33.7
8. Hyperbolic functions	26	31.3
9. One-to-one and inverse functions	25	30.1
10. Inverse Hyperbolic functions	24	28.9
11. Polar Curves	24	28.9
12. Parametric Differentiation	23	27.7
13. Derivative of an inverse functions	22	26.5
14. Polar Coordinates	22	26.5
15. Determinants	22	26.5
16. Logarithmic Differentiation	19	22.9
17. Methods of Integration	19	22.9
18. Logarithms	18	21.7
19. Trigonometry	17	20.5
20. Index and Sigma Notation	17	20.5
21. Elementary Differentiation	16	19.3
22. Limits	15	18.1
23. Geometry	13	15.7
24. Surds	11	13.3
25. Factorisation	10	12.0
26. Algebraic Fractions	10	12.0
27. Indices	10	12.0
28. Functions	10	12.0
29. Quadratic Equations	10	12.0

There is an expectation that an average student is expected to undertake 12 hours of work to complete a one-session six-credit point subject. Student responses to the question ‘Including lectures and tutorials and work outside class, on average per week how much time did you spend for the first twelve weeks of session working on MATH141?’, indicated that 67% of students did eight hours or less per week, while only 5% of students completed 12 or more hours per week (Table 5.19). From this perspective, creating an additional resource that students are willing to use appears to be reasonable.

Table 5.19 Time Spent Working on MATH141 during the First Twelve Weeks of Session

	Time spent per week	
	N	**%**
0-2 hours	13	15.7
3-5 hours	14	16.9
6-8 hours	29	34.9
9-11 hours	22	26.5
12-14 hours	1	1.2
More than 14 hours	3	3.6
No response	1	1.2
Total	83	100.0

To the question ‘Do you consider that you have completed the lecture component by …’, 18% of the respondents answered ‘attending virtually all the lectures’ (n = 15), 48% refer to ‘attending virtually all the lectures and doing the exercises as they are required for assessment’ (n = 40), and 19% chose the option ‘attending virtually all lectures and doing the exercises in the textbooks’ (n = 16), 13% answered ‘Other’ (n = 11) and 1% did not answer (n = 1).

Motivating students through making subjects relevant is often an important part of successful teaching. After completing 12 weeks of MATH141, 47% of students saw mathematics as more relevant to their life and/or anticipated profession (n = 39), 6% students now viewed mathematics as less relevant to my life and/or anticipated profession (n = 5), 42% students considered mathematics to have the same relevance as when I commenced (n = 35) and 5% students did not answer this question (n = 4).

Assessment is also seen as an important way of influencing learning outcomes. In mathematics, as in other disciplines, the issue of academic integrity also arises, with concerns over student cheating. ‘Do you consider that the assessment system is fair and that students basically earn the marks they get or is it rife with cheating or...?’, 53% students responded that it was fair (n = 44), 45% students did not answer (n = 37) and the remaining students provided additional comments reflecting the nature of assessment:

Distribution of marks

> A lot of pressure put on last exam!

> Yeah pretty much. Didn't really agree with people getting ... extra marks from the basic skills though.
>
> More marks should be given on the tutorials and assessments.

Sources of inequity

> It is unfair for mature aged students who have not came straight from high school [perhaps a reference to the unannounced test in week 1 attracting marks].
>
> It is fair. Except some tutorial quizzes are less formal for some tutorial classes and gives them the ability to cheat.
>
> It is fair. However, those students who do not attend PASS are disadvantaged as the assignments are done in this time.

Equitable

> Marks are fair, assignments are challenging but not impossible.
>
> Think that the students who get good marks work hard to get them and a few cheat through assignments and quizzes to just pass and or still fail.
>
> It is fair as the value of the mid session plus final tests very depending on the student. This allows the student to get their test mark.
>
> Different assignments for different tutorials mean some get it easy some get it hard.
>
> I think if you work hard in this subject you are awarded accordingly.

Need for co-operative learning

> I believe it is fair, the tutorial assignments were often completed via collaboration between peers; however, I think that working with others in maths is necessary and beneficial. Perhaps tutors should discuss tutorial assignments together as my peers and I.

There is a tension in mathematics where individual work and individual completion of assessment is required by the lecturers but where students identify the need for co-operative learning opportunities. Perhaps the structuring of teaching could involve more collaborative work prior to the assessment, possibly on similar questions or even the provision of group projects or assignments. At present, however, in this subject collaboration on assessment would be considered plagiarism. While the video resources did not meet the need of students to collaborate with others, they did allow students to legitimately access helpful resources when preparing resources.

When an open-ended question asked 'How best can MATH141 be improved?', the comments were similar to those provided at the mid-session survey. There were obvious concerns about lecturing on, and resources associated with, the 'vectors' topic, with a specific suggestion that

> Sometimes the teaching methods of the different lecturers can be rather confusing overall. I think one lecturer would be better.

As discussed earlier there was request for additional resources:

> Better lecture notes, more online videos.

Additional suggestions included:

> Put more examples into the notes.
>
> Put more worked solutions in book, give us a cheat sheet.
>
> Have all the formulas in the notes that are expected to be known.
>
> Less jargon.

The structuring of some aspects of the subject was also raised, specifically:

> No tests on Saturday.
>
> Remove the attendance requirement. I have refused to sign it all year.
>
> Finish the sections than moving to another for example, not having lectures about matrices and fundamentals at the same time.
>
> This is an exam on our knowledge not how tricky you think you are.

Other students identified motivational issues:

> Give more incentive/requirement to have additional outside work done.
>
> Give people more hope.
>
> More time solving actual problems with people to help and show you how.

> I think it should be related to real life. One lecturer does a good job at this for engineering but not every one is doing that course.

5.4 Conclusion

The methodology that has been developed can be used to deliver resources in other disciplines, particularly technical subjects such as engineering and the physical sciences. Showing students how to solve problems by combining a visual component, showing a solution being developed, with an audio component, explaining the thought processes of the solver, can be fruitfully applied to improve the learning experience of students across the whole spectrum of courses offered at university level.

Video resources were trialled for the first time in Autumn 2006. Almost all students who used the resources commented that their use had helped improve their understanding of mathematical concepts. The analysis showed that the performance of weaker students who used these resources matched that of better students who did not use them.

From all the data collected from students in 2006, it was apparent that video resources could significantly improve the mathematical skills of weaker students, however the improved performance evident at the Mid-Session Test was not evident in the final subject outcomes, where overall pass rates remained the same as in the previous years. It was not sufficient to provide students with transitional materials that allowed them to 'catch-up'. The data seemed to suggest that learning support is necessary for students throughout the subject. For this reason, in 2007 further video resources were created which nearly doubled the original quantity. The resources produced increased the amount of resources available in some topics as well as extending to topics that were new to students. In the next chapter, investigations will examine the impact on learning outcomes over the period 2004-2007 as the number of video resources changed from none, to transitional resources, to resources for all topics across the subject.

Chapter 6

Implementation of Video Resources

6.1 Introduction

Having designed and developed a set of learning resources, the next stage involved an evaluation of the outcomes in the implementation phase. Specifically the aims of this chapter are to:

- explore the impact of the video resources on learning outcomes by examining changes in performance for two cohorts of students: 2004 and 2007,
- explore further what is meant by students when they suggest that the video resources are useful, that is, seek to find out what aspects of learning or understanding have been affected and
- identify the next steps for improving video resources for students in the introductory mathematics subject, MATH141.

Evaluation in the implementation phase takes place in a particular context. Hence, some of the key considerations when undertaking the evaluation in this phase relate to key findings from Chapter 5. Specifically, the following should be noted:

- The questions in the Basic Skills Tests were the same for the years 2004 and 2007.
- When comparing the student intakes for 2004 and 2007, no significant difference was found between the mean marks or variances for Basic Skills Test 1 in the two years. That is, there was no difference in mean baseline skills performance.
- Comparison of differences in the performance of individual mathematical skills between the 2004 and 2007 cohorts revealed only one difference with the 2004 cohort outperforming the 2007 cohort in arithmetic with substitution.
- No video resources were available in 2004 and 2005. Transitional video resources were available in 2006, and video resources for all topics were available in 2007.
- In 2006, when video resources were available for the four weeks of fundamental skills revision, students who used video resources were found to have significantly lower entry level skills than those who did not use the video resources.
- In 2006, by the time of the Mid-Session Test, the weaker students who used the video resources did not have significantly different mean marks from those who had not used the resources.
- In 2006, there was no overall improvement in the failure rate suggesting that video resources might need to be extended to cover all topics in the subject, not just the fundamental skills being reviewed in the first four weeks.
- Final grades in MATH141 were dominated (80%) by marks obtained on the new or later topics rather than on the skills obtained in the first four weeks.

6.2 Data Sets

During this case study the curriculum was unchanged and the structure of the assessment system remained the same from year to year. The subject coordinator is the only one of the three lecturers who has been teaching the subject since 2004. The other two lecturers in the subject have changed. For this part of the research, triangulation has involved accessing different data sources, collecting complementary data, recognising when innovations were introduced and making sense of the changes that were then observed.

In Chapter 3, some of these data were analysed from the perspective of establishing baselines in mathematical skills. Other data discussed in Chapter 5 allowed examination of changes based on a partial set of video resources being made available to students. In this chapter the impact on performance is examined from the perspective of having a set of mathematics learning resources covering all topics. The data sets also allowed examination of the relative impact of the video resources in the context of several other learning resources being available to students. When analysis of the Basic Skills Tests and the Mid-Session Test revealed inconsistencies, further data were sought to investigate the impact of the learning resources. These data sets are summarised in Table 6.1.

Table 6.1 Data Sets Collected or Accessed to Determine Impact of Learning Resources

Data Set	Use
Data for the same test questions in 2004 and 2007 • Basic Skills Test 1, • Basic Skills Test 2 and • Mid-Session Test.	Allows identification and examination of • changes in mathematics skills performance, • overall changes in performance from Basic Skills Test 1 to Basic Skills Test 2, and from Basic Skills Test 1 to the Mid-Session Test; for 2004 and 2007 students and • comparison of performance in different topic areas in Basic Skills Test 2 and the Mid-Session Test.
Final mark and pass rates 2000-2007 the University of Wollongong database, Cognos	Provides baseline and final outcome data on failure rates and other grades. Permits examination of change in pass rates after the innovation.
Data for the assessment with questions of a similar standard in 2004 and 2007 • quizzes, • assignments and • exam and topic areas.	These data were used to clarify seeming contradictions in findings from the use of Basic Skills Test 1, Mid-Session Test and final marks.
Change evaluation 2006 and 2007 with additional questions about learning from video resources (2006, 2007)	These permit a comparison between the 2005 class, before video resources were introduced, 2006 after partial availability of video resources and 2007 after video resources were introduced for all topics. These also permit: • the evaluation of the video learning resources in the context of other resources made available to students and • examination of students' confidence in each skill area. They lead to recommendations as to what to do next to improve learning outcomes.

6.3 Learning Outcomes: Performance on the Same Tasks

The learning outcomes that can be explored in relation to the introduction of innovations are many and varied. In this study, a comparison of the 2004 and 2007 cohorts has been explored for:

- performance in Basic Skills Tests 1 and 2 with identical questions,
- performance in the Mid-Session Test with 21 identical questions,
- performance in specific skills areas and
- final pass rates, failure rates and grade shifts.

Changes have also been examined in relation to:

- different aspects of understanding and learning that have changed,
- perceived usefulness by students of the learning resources and
- confidence in performing mathematical skills.

6.3.1 Performance in Basic Skills Test 2

Comparison of performance in basic skills involves two aspects: changes in mathematics skills and overall performance.

6.3.1.1 Changes in Specific Skills on Basic Skills Test 2

As reported in Chapter 3, at baseline the profile of the best and worst performed skills was the same for 2004 and 2007 students. On only one skill, ‘arithmetic’ with substitution, was there a different in performance, with the 2004 cohort performing better.

For Basic Skills Test 2 (Table 6.2) the four best skills (82-91% correct) were the same in 2004 (before the introduction of video resources) and 2007 (after the introduction of resources). As can be seen from Figure 6.1 these skills were: ‘indices’, ‘trigonometry’, 'inequalities' and 'factorisation'. For less well performed skills, however, where there is greatest scope for change, the patterns of correct responses are quite different between 2004 and 2007, with significant improvement in four of the five worst performed skills.

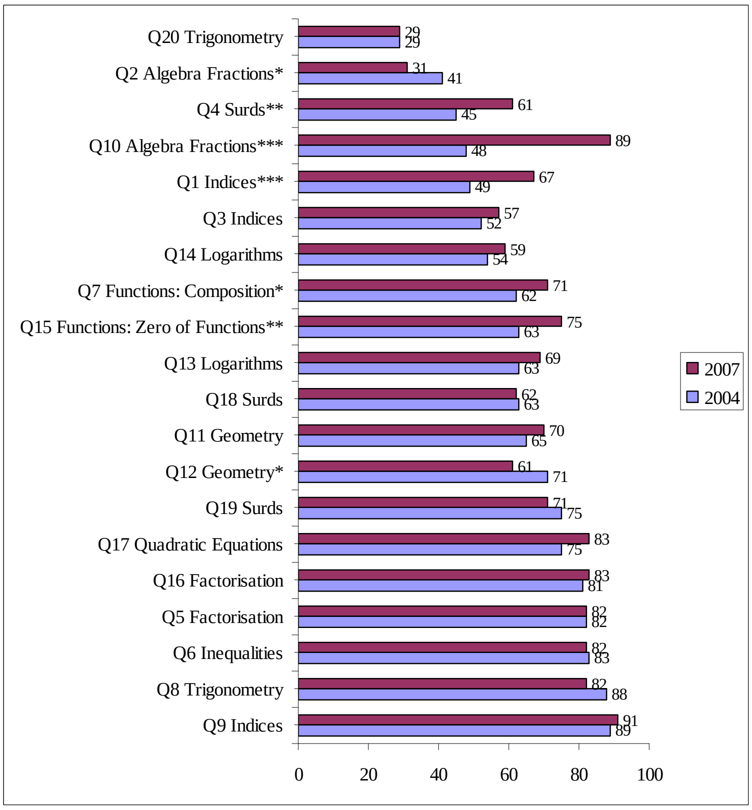


Figure 6.1 Comparison of Percentage of Correct Responses for Topics in Basic Skills Test 2 for 2004 and 2007
$* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

The percentages of correct responses to the twenty questions in Basic Skills Test 2 are presented in Table 6.2 and questions with all options are in Appendix 2. For the Basic Skills Tests, in 2004 students were allowed to use a calculator but in 2007 students were not allowed to use a calculator. An examination of the questions revealed, however, that the 2004 cohort was not, in fact, advantaged.

Table 6.2 Basic Skills Test 2 in 2004 and 2007, Ranking Worst to Best Answers in 2004

N	Topics	Question	% Correct 2004 N=193	% Correct 2007 N=218
20	Trigonometry	If $\sin x = \frac{4}{5}$ and $\frac{\pi}{2} \le x \le \pi$, then the exact value of $1 - \tan x$ is	28.5	28.7
2*	Algebra Fractions	$\frac{x}{x+1}$ equals	41.3	31.4
4**	Surds	$\sqrt{a^2 - b^2}$ is equal to	44.8	60.5
10***	Algebra Fractions	Rearrange the following equation to find y: $\frac{1}{x} + x = \frac{1}{y}$.	47.7	89.2
1***	Indices	$2^a 4^b$ equals	49.4	66.8
3	Indices	$\frac{x^n}{x^{n-1}}$ equals	52.3	57.4
14	Logarithms	If $\ln a = 2$ and $\ln b = 3$, evaluate $\ln(ab^2)$.	54.1	58.7
7*	Functions: Composition of Functions	If $f(z) = 2z + 1$ and $g(x) = \frac{1}{x}$ what is $g(f(a))$?	61.6	71.3
15**	Functions: Zero of Functions	Suppose that $f(x)$ is a polynomial. Which of the following statements is True?	62.8	74.9
13	Logarithms	Let x, y, b and N be positive real numbers. Which of the following statements is false?	63.4	69.1
18	Surds	$\left(\sqrt{8} - \sqrt{2}\right)^2$ equals	64.0	62.3
11	Geometry	$2x + 2y = 9$ is the equation of	64.5	70.4
12*	Geometry	The equation of the line through (-1,2) and perpendicular to the line $y + 2x + 3 = 0$ is given by	70.9	61.0
19	Surds	$\frac{3}{\sqrt{5}+2}$ is equal to	75.0	70.9
17	Quadratic Equations	Find the roots of the quadratic: $x^2 + 1 = 5x$	75.0	82.5
16	Factorisation	$f(x) = 2x^3 - 3x^2 - kx + 20$ has $x - 5$ as a factor when	80.8	82.5
5	Factorisation	Factorise $2x^2 - 3x - 2$.	82.0	81.6
6	Inequalities	For what values of x is $\lvert x - 3 \rvert < 15$?	82.6	81.6
8	Trigonometry	What is $\sin \frac{\pi}{2}$?	87.8	82.1
9	Indices	If $f(x) = 2^x$ what is 2^0?	89.0	91.0

* p < 0.05, ** p < 0.01, *** p < 0.001

Tests for differences in the proportion of correct responses for the 2004 and 2007 cohorts revealed significant differences for seven of the twenty questions. Students in 2007 had a significantly greater proportion of correct responses for the questions involving: surds ($Z = 3.12$, $p < 0.01$), algebra fractions ($Z = 9.04$, $p < 0.001$), indices ($Z = 3.49$, $p < 0.001$), composition of functions ($Z = 2.03$, $p < 0.05$) and zero of functions ($Z = 2.59$, $p < 0.01$).

The students in 2004 performed better than the students in 2007 on algebra fractions ($Z = -2.03$, $p < 0.05$) and geometry ($Z = -2.06$, $p < 0.05$).

6.3.1.2 Changes in Overall Performance in the Basic Skills Tests

The means and standard deviations for the Basic Skills Tests are presented in Table 6.3. Using Paired t-tests, a significant improvement in the mean from Basic Skills Test 1 to Basic Skills Test 2 was found in the years 2004 ($t_{144} = 8.26$, $p < 0.001$), 2005 ($t_{139} = 3.76$, $p < 0.001$), 2006 ($t_{166} = 6.32$, $p < 0.001$) and 2007 ($t_{184} = 12.86$, $p < 0.001$). The primary comparison of interest is between the test scores in the years 2004 and 2007, as the questions for the Basic Skills Tests were the same only in 2004 and 2007.

Table 6.3 Changes during Years 2004-2007

	Basic Skills Test 1 (BST1)			**Basic Skills Test 2 (BST2)**			**BST2 - BST1**		
	N	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
2004	177	11.18	3.94	170	12.73	3.75	145	2.33	3.40
2005*	150	10.80	3.54	163	11.61	3.53	140	1.02	3.22
2006*	175	9.66	3.49	194	11.57	3.52	167	1.59	3.21
2007	194	10.68	3.94	222	13.93	3.77	185	3.13	3.32

* Tests were not the same as for 2004 and 2007

An independent t-test on Basic Skills Test 2 in 2004 and 2007 revealed that the 2007 cohort with video resources had a significantly higher mean performance ($t_{390} = 3.14$, $p = 0.002$) than the 2004 cohort without resources. A one-tailed independent t-test on the change scores, that is, BST2 mark less BST1 mark, revealed a significant difference in the average change scores ($t_{328} = 2.15$, $p = 0.033$) with a mean change of 3.13 in 2007 compared to a mean change of 2.33 in 2004. Improvements were significantly greater in

2007 when there were video resources than in 2004 when there were not. The change of 3.13 represents a percentage change from the BST1 mean of 29% in 2007 compared to 21% for 2004. A Levene's test for homogeneity of variance revealed no difference in the variances of the change scores ($F = 0.02$, $p = 0.90$).

6.3.2 Performance in the Mid-Session Test

For the Mid-Session Test, as for Basic Skills Test 2, it was possible to examine changes in specific skills as well as overall performance.

6.3.2.1 Changes in Specific Skills in the Mid-Session Test

For the Mid-Session Test, twenty-one questions were the same in 2004 and 2007 and four questions were different. The percentages of correct answers to the twenty-one questions in the Mid-Session Test are presented in Table 6.4 and questions with all options are provided in Appendix 3. Two questions on elementary differentiation and one on differentiation of trigonometric function were the three best questions (78-92% correct) for both cohorts with and without video resources (Table 6.4).

Tests for differences in the proportion of correct answers for the 2004 and 2007 cohorts revealed significant differences in six of the twenty-one questions. As can be seen from Figure 6.2, the worst question in 2004, on 'determinants', was performed significantly better in 2007 ($Z = 2.32$, $p < 0.05$). The next five worst performed questions were all on matrices. Two of these questions were performed better in 2004 than in 2007, specifically these were questions on the 'reduced echelon form' ($Z = -2.96$, $p < 0.01$) and 'system of equations' ($Z = -2.78$, $p < 0.01$). These were later topics in the matrix lecture strand. In 2007, students commented after the Mid-Session Test that 'matrices' topic had not been covered completely prior to the test. One student commented in the change evaluation 'Teach topics BEFORE they are examined'. It is possible that these were not covered in some students' tutorials or perhaps even in lectures attended by all students, or maybe the attention given to them in the formal parts of the subject was inadequate relative to other material.

Students performed significantly better in 2004 than did students in 2007 for questions on: differentiation of parametric functions ($Z = -2.34$, $p < 0.05$), limits ($Z = -2.82$, $p < 0.01$) and elementary differentiation ($Z = -2.36$, $p < 0.05$).

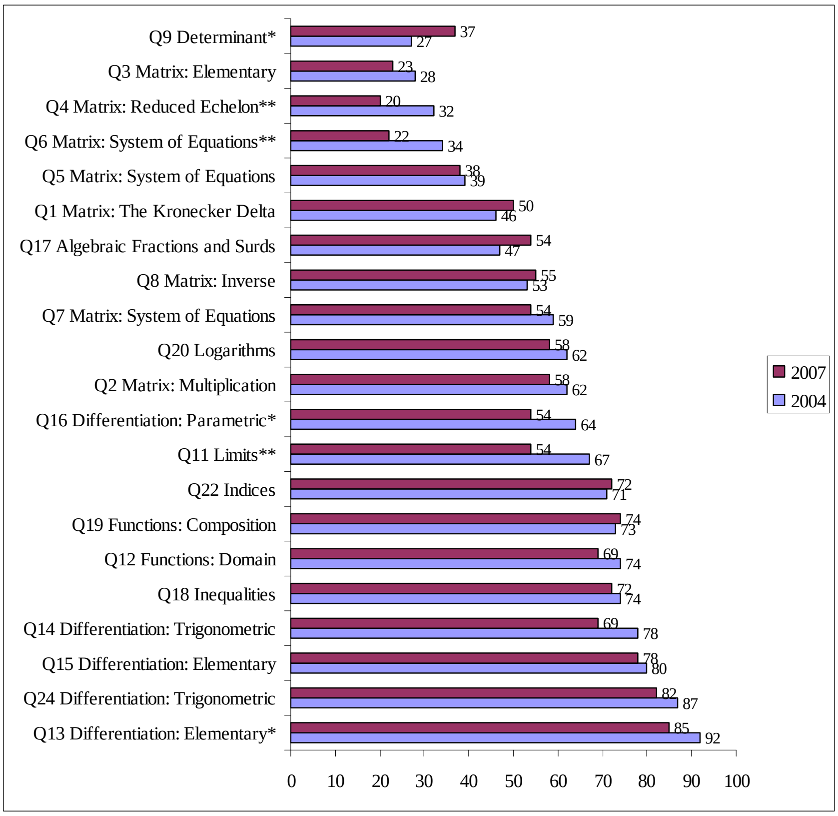


Figure 6.2 Comparison of Percentage of Correct Responses for Topics in the Mid-Session Tests for 2004 and 2007
* $p < 0.05$, ** $p < 0.01$

Table 6.4 Mid-Session Test in 2004 and 2007, Ranking Worst to Best Answers in 2004

Number	Topics	Question	% Correct	
			2004 N=205	**2007 N=254**
9*	Determinants	The determinant of the matrix $\begin{pmatrix} 1 & 0 & 2 & -3 \\ 0 & 0 & 5 & 0 \\ -2 & 6 & 1 & 9 \\ 0 & 3 & -8 & 1 \end{pmatrix}$ is equal to	26.8	37.0
3	Matrix: Elementary	Of the following, the matrix that is **NOT** an elementary matrix is	28.3	22.8
4**	Matrix: Reduced Echelon Form	Given the matrix $A = \begin{pmatrix} 1 & -1 & 2 & 0 \\ -1 & 1 & -1 & -1 \\ 2 & -2 & 7 & -2 \\ -2 & 2 & -5 & 3 \end{pmatrix}$, the reduced echelon form for A is given by	32.2	20.1
6**	Matrix: System of Equations	Given that $A = \begin{pmatrix} 1 & 2 & -4 \\ -1 & 1 & 1 \\ 1 & 5 & -7 \end{pmatrix}$, $\underset{\sim}{b} = \begin{pmatrix} 1 \\ -1 \\ 2 \end{pmatrix}$ and $\underset{\sim}{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$, the solution to the system of equations $A\underset{\sim}{x} = \underset{\sim}{b}$ is	33.7	22.1
5	Matrix: System of Equations	For a homogeneous system of equations with matrix of coefficients A, if the rank of A is less than the number of rows in A, then the systems has	39.0	38.2
1	Matrix: The Kronecker Delta and Sigma Notation	Let A=$\left(a_{ij}\right) = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix}$ and let δ_{ij} be the Kronecker delta. Then the expression $\sum_{k=1}^{3}\sum_{i=1}^{3} a_{ki}\delta_{3k}\delta_{i2}$ is equal to	45.9	49.6
17	Algebraic Fractions and Surds	By rearranging the equation $\sqrt{\frac{1}{y} - \frac{1}{x}} = \frac{1}{4}$ y can be found to be	46.8	54.3
8	Matrix: Inverse of a Matrix	Given that $A = \begin{pmatrix} 1 & 2 & 0 \\ -1 & 0 & 1 \\ 0 & 2 & 0 \end{pmatrix}$, $\underset{\sim}{b} = \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ and $\underset{\sim}{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$, then	53.2	54.7

Continued over page …

Table 6.4 (*Continued*) Mid-Session Test in 2004 and 2007, Ranking Worst to Best Answers in 2004

Number	Topics	Question	% Correct 2004 N=205	% Correct 2007 N=254
7	Matrix: System of Equations	The value of k for which the system given by $3x+2y=11$, $6x+ky=21$ has (i) a unique solution (ii) no solutions (iii) infinitely many solutions	58.5	53.5
20	Logarithms	If $\ln x = 7$ and $\ln y = 2$, then the value of $\ln\left(\frac{x^2}{y}\right)$ is	62.0	57.9
2	Matrix: Multiplication	Given that $A=\begin{pmatrix} 3 & 6 \\ -4 & -8 \end{pmatrix}$, and $B^T = \begin{pmatrix} -10 & 5 \\ -4 & 2 \\ 2 & 1 \end{pmatrix}$, the matrix product AB is	62.4	57.5
16*	Differentiation: Parametric Functions	If $y(t) = e^t(\cos t + \sin t)$ then $\frac{dy}{dx}$ is given by	64.4	53.5
11**	Limits	The value of the limit $\lim_{x\to 1}\frac{x^4-1}{x-1}$	67.3	54.3
22	Indices	If $2^x = 2\frac{1}{2}$ and $2^y = 3$, then 2^{x+y} is equal to	71.2	72.4
19	Functions: Composition of Functions	If $f(z) = 2z+1$ and $g(x) = \frac{1}{x}$ then $f(g(a))$ is given by	73.2	74.0
12	Functions: Domain of Functions	The largest possible domain for the function $f(x) = \sqrt{\ln x - 1}$ (where $f(x)$ is real-valued) is	74.2	68.9
18	Inequalities	If $\lvert x+2\rvert > 1$ then	74.2	71.7
14	Differentiation: Trigonometric Functions	If $y = \sin 2x$ then $\frac{dy}{dx}$ is given by	77.6	69.3
15	Differentiation: Elementary	If $f(x) = \frac{1}{(1-3x)^2}$ then $\frac{df(x)}{dx}$ is given by	79.5	78.0
24	Differentiation: Trigonometric Functions	If $y = \frac{\sin x}{x}$ then $\frac{dy}{dx}$ is given by	86.8	81.9
13*	Differentiation: Elementary	If $y = \frac{2}{x^3}$ then $\frac{dy}{dx}$ is given by	92.2	85.0

$* \ p < 0.05$, $** \ p < 0.01$

6.3.2.2 Changes in Overall Performance in the Mid-Session Test

The means and standard deviations for Basic Skills Tests 1, the Mid-Session Tests and the change scores, that is, the Mid-Session Test minus Basic Skills Test 1, are presented in Table 6.5 for the years 2004 and 2007.

Table 6.5 Changes in the Mid-Session Test and Basic Skills Test 1 in Years 2004 and 2007

	Basic Skills Test 1 (BST1)			**Mid-Session Test (MST)***			**MST - BST1****		
	N	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**
2004	177	11.18	3.94	215	11.91	3.69	171	2.66	3.94
2007	194	10.68	3.94	254	11.77	3.65	193	2.83	4.18

* For 21 questions that were the same in 2004 and 2007
** For 25 questions in MST

An independent t-test on the Mid-Session Tests in 2004 and 2007 revealed that there were no differences in the average of student marks based on the twenty-one questions that were the same ($t_{467} = 0.42$, $p = 0.67$) and there was no significant difference in variances ($F = 0.00$, $p = 0.993$). Furthermore, there was no significant difference in the average marks based on all twenty-five questions for the Mid-Session Tests in 2004 and 2007 ($t_{467} = 0.65$, $p = 0.52$) nor was there any difference in variances ($F = 0.006$, $p = 0.94$). An independent t-test revealed no significant difference in the change of marks from BST1 to MST ($t_{362} = 0.42$, $p = 0.68$) when comparing the 2004 cohort (mean = 2.66, s.d. = 3.94) with the 2007 cohort (mean = 2.83, s.d. = 4.18).

Data regarding the perceived value of the lectures and their contribution to student understanding and learning is not available prior to 2005. From 2005 to 2007 data showed that the evaluations for one lecture strand, ‘matrices and determinants’, had declined from 2006 to 2007. This provided one possible explanation for the decline in performance in the matrix questions in the Mid-Session 2007 cohort when compared with the 2004 cohort. Another possible explanation is that the student cohorts are different. As discussed in Chapter 2, there has been evidence from other universities worldwide that suggests a decline in performance attributable to lower entry skills. Here, however, based on entry skills, the 2004 students at least were not found to differ from the 2007 cohort. A third possibility had to do with the coverage provided by the lecture notes. Examination of the lecture notes for 'matrices' revealed that they were the same in 2004 and 2007.

6.4 Failure Rates, Pass Rates and Shifts in Grades

Prior to the establishment in 2004 of the faculty-based working party QUALITY101, failure rates moved from a low of 22% in 2001 to 31% in 2002, as shown in Table 6.6. Again, one plausible explanation for the move from 22% to 31% has to do with the changes in the lecturing staff involved. Nevertheless, in recent years, failure rates in MATH141 and the equivalent subject (offered in the following teaching session) had been high and appeared to be intractable, despite there being a change in two of the lecturing team each year.

One possible explanation for the failure to improve pass rates from 2005 to 2006 was that the video resources were directed toward 20% of the assessment of the subject with fundamental skills being assessed in some quizzes, assignments, and part of the Mid-Session Test. Bonus marks were also awarded for successful completion of both Basic Skills Tests. Resources were not available for 80% of the assessment of work that was related to new topics. For instance, there were no video resources on 'vector geometry', which represented 25% of the subject. It was considered plausible that simply bringing background skills up to an acceptable level is not sufficient to have an impact on overall outcomes. Support may be required throughout the subject. As a consequence, resources were extended to cover all new topics.

Table 6.6 Pass Rates for MATH141*

Year	N	Fail	Pass Conceded & Pass	Credit	Distinction	High Distinction
2000	155	23.9	43.9	21.3	5.8	5.2
2001	143	22.4	49.7	17.5	7.0	3.5
2002	177	31.1	47.1	14.1	5.7	1.2
2003	185	24.5	42.7	16.2	9.7	4.9
2004	207	28.0	43.5	13.0	10.1	5.3
2005	179	30.7	42.5	13.4	10.1	3.4
2006	209	28.7	50.7	13.4	4.3	2.9
2007	241	20.7	43.5	16.6	13.7	4.1

Data Source: the University of Wollongong, Cognos Data Base, 22/08/2007

In 2007, the proportion of students failing fell significantly compared to the overall proportion failing between 2000 and 2006 ($Z = 2.10$, $p < 0.05$). Further, there was a significantly higher mean mark ($t_{446} = 2.38$, $p = 0.018$) for the 2007 cohort with video resources (mean = 56.90, s.d. = 17.83, n = 238) than the 2004 cohort without resources (mean = 52.66, s.d. = 19.89, n = 210). An examination of student grades also revealed that the proportion of students with distinction or high-distinction grades was also the highest on record over this period (17.8%). The shift to higher grades was also a positive outcome in terms of expected performance in follow-on subjects as students with a bare pass in the subject have a much higher risk of failing the follow-on subject, MATH142. At the time of completion of this research, it was not possible to ascertain if there was an associated follow-on effect in the pass rates of MATH142 students, although it is clear from an evaluation of MATH142 students in 2006 that these students would like access to video resources:

- More resources is the number one way this subject could be improved. … MATH141 was great. Worked solutions in PDF and video. Worked solutions to past exams would also be appreciated.
- Provide more step by step answers to exercises and online video tutorials similar to those in MATH141 (Porter 2006b).

6.5 Learning Outcomes: Performance on Similar Tasks

One of the inexplicable finding is that the performance in the Mid-Session Test did not show a significant improvement in 2007 when compared to 2004. Indeed, on the basis of individual skills, students performed better in 2004. In the researcher’s own tutorial class there was some criticism in 2007 that topics such as ‘matrices’ had not been covered before being tested on the Mid-Session Test. However, this did not explain all the differences. There appeared to be an inexplicable leap from the ‘equivalent’ results in the Mid-Session Test to the lower failure rate in the subject overall; therefore it was decided to examine the other assessment in the subject to see if it was possible to explain the unexpected performance in the Mid-Session Test and the drop in failure rates. To do this, the remaining data for assessment were accessed, that is, data from quizzes, assignments and the final examination. These assessment tasks were not the same for the two cohorts although it is intended that they be comparable and of a similar standard from year to year.

6.5.1 Changes in Examination Performance

An independent t-test revealed a significant differences in the Final Examination (t_{456} = 3.03, p = 0.003) with the 2007 cohort performing better (mean = 49.88, s.d. = 21.06) than the 2004 cohort (mean = 43.82, s.d. = 21.63). A Levene's test for equality of variances revealed there was no significant difference in the variances in the exam marks between two years (F = 0.15, p = 0.70).

As exam marks are recorded for the four questions corresponding to the topic areas (Table 6.7), it was possible to undertake further analysis.

Table 6.7 Exam Results in Years 2004 and 2007

Question	Topic	2004			2007		
		N	Mean	S.D.	N	Mean	S.D.
1	Matrices and Determinants†	215	11.46	5.81	243	12.53	5.92
2	Functions and Limits*	215	11.25	5.87	243	14.26	5.55
3	Vectors*	215	9.29	6.42	243	11.89	7.18
4	Differentiation, Integration, and Polar Coordinates	215	11.82	6.62	243	11.20	5.95
Total		215	43.82	21.63	243	49.88	21.06

* p < 0.001
† Borderline significant

As a Levene's test for the equality of variances revealed differences in variances for the marks in the 'vectors' question when comparing the 2004 and 2007 cohorts ($F_{1, 456}$ = 7.25, p = 0.007), four independent t-tests were used to follow up the multivariate analysis. An independent t-test showed students in 2007 performed significantly better in question 2 on the topics of functions and limits (t_{456} = 5.64, p < 0.001) and for question 3 on 'vectors' (t_{456} = 4.06, p < 0.001) than students in 2004. The result of an independent t-test was borderline significant for question 1 on 'matrices and determinants' (t_{456} = – 1.95, p = 0.05), while no significant difference in performance was found for question 4 on the topics of 'differentiation', 'integration' and 'polar coordinates' (t_{456} = 1.06, p = 0.29). As has been found throughout, there appears to be greatest scope for improvement where topics are performed least well.

To be confident that the improvement has more to do with the resources than an easier paper, the questions were examined for the topic areas and the lecturers were asked to compare the difficulty of the questions.

In each year, the time allowed to do the MATH141 exam is three hours and 15 minutes, which can be equated to 45 minutes for each question and 15 minutes for review. A comparison of examination papers in 2004 and 2007 revealed that the papers appeared to be equivalent in length. It also showed the following:

Question 1: Matrices and Determinants

For this question, the difference in mean mark between 2004 and 2007 just failed to be significant; the degree of difficulty in 2007 was slightly more than in 2004. As can be seen from Figure 6.3 the number of sub-questions in 2007 was more than of the number of sub-questions in 2004.

2004

Question 1 (*Use a separate book for your answers to Question 1.*)

(a) Consider the following matrices.

$$A = (a_{ij}) = \begin{pmatrix} 2 & 1 \\ 3 & 4 \end{pmatrix} \qquad B = (b_{ij}) = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}$$

$$C = (c_{ij}) = \begin{pmatrix} -2 & 3 & -1 \\ 4 & -6 & 2 \end{pmatrix} \qquad D = (d_{ij}) = \begin{pmatrix} 3 & 5 \\ 1 & 4 \end{pmatrix}$$

(i) Evaluate $\sum_{n=1}^{2}\sum_{k=1}^{3} c_{n2}a_{k1}\delta_{nk}$.

(ii) If possible, evaluate $(A - D)C$ and C^TB.
Where the calculation is not possible, give a brief reason.

(iii) Let $\underset{\sim}{x} = \begin{pmatrix} x \\ y \end{pmatrix}$. If possible, find the solution to the homogeneous system $C^T\underset{\sim}{x} = \underset{\sim}{0}$.

(iv) Find the rank of the matrix B.

(v) Calculate the determinant of D, $|D|$, and determine whether D^{-1} exists or not. Do **NOT** find D^{-1}.

(vi) Show that the eigenvalues of A are $\lambda = 1$ and $\lambda = 5$. Find the eigenvectors corresponding to the eigenvalue $\lambda = 1$.

(b) Consider the system of equations $A\underset{\sim}{x} = \underset{\sim}{b}$, where

$$A = \begin{pmatrix} 2 & -1 & 1 \\ -1 & 1 & 2 \\ 1 & -2 & -1 \end{pmatrix}, \quad \underset{\sim}{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}, \quad \text{and} \quad \underset{\sim}{b} = \begin{pmatrix} 3 \\ -3 \\ 0 \end{pmatrix}.$$

(i) Reduce the augmented matrix $\left(A \middle| I \middle| \underset{\sim}{b}\right)$ to echelon form, $\left(A^E \middle| I^E \middle| \underset{\sim}{b}^E\right)$.

(ii) Write down the elementary matrices, E_1, E_2, E_3, corresponding to the first three row operations performed in part (b)(i).

(iii) Reduce the augmented matrix $\left(A \middle| I \middle| \underset{\sim}{b}\right)$ to reduced echelon form, $\left(A^R \middle| I^R \middle| \underset{\sim}{b}^R\right)$.

(iv) If possible, find A^{-1} and the solution to the system, $\underset{\sim}{x}$.

(v) If $\underset{\sim}{x}$ was found in part (b)(iv), verify the value for y using Cramer's Rule.

2007

Question 1 (*Use a separate book for your answers to Question 1. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) Let $A = \begin{pmatrix} 0 & 1 & 1 \\ 1 & -1 & 1 \\ 2 & 3 & 7 \end{pmatrix}$, $\underline{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$ and $\underline{b} = \begin{pmatrix} -1 \\ 0 \\ -5 \end{pmatrix}$.

(i) Write down A^T, the transpose of the matrix A.

(ii) Compute $\det A$, the determinant of the matrix A.

(iii) Using no more than three elementary row operations, reduce the augmented matrix $(A \mid \underline{b})$ to echelon form, $(A^E \mid \underline{b}^E)$.

(iv) Hence, or otherwise, find the solution of the matrix equation $A\underline{x} = \underline{b}$.

(v) Is there a solution to $A\underline{x} = \underline{b}$ with $y = 1$? If so, write down the corresponding $\underline{x}$. If not, explain why not.

(vi) Write down the elementary matrices E_1, E_2, E_3 corresponding to the row operations performed in (iv).

(vii) Write down the simplified product of matrices EA, where $E = E_3E_2E_1$.

(b) Let

$$B = \begin{pmatrix} 1 & 2 \\ 2 & -2 \end{pmatrix}.$$

(i) Write down the polynomial equation satisfied by the eigenvalues λ of B.

(ii) Hence, or otherwise, find the eigenvalues of B.

(iii) Find an eigenvector corresponding to each eigenvalue of B.

(iv) Using matrix multiplication and addition, verify that

$$B^2 + B - 6I = Z,$$

where I is the 2×2 identity matrix and Z is the 2×2 zero matrix.

(v) Multiply the equation in (iv) by B^{-1} and rearrange, to obtain down a formula for B^{-1}, *in terms of* B.

(vi) Using the formula from (b) (v), or otherwise, compute B^{-1} in the form

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix}.$$

(vii) Verify that $BB^{-1} = I$.

(viii) Using the result of (b) (vi), or otherwise, solve the following systems of linear equations:

$$(I) \quad \begin{aligned} x + 2y &= 0 \\ 2x - 2y &= 0 \end{aligned}$$

Figure 6.3 Question 1 in the 2004 and 2007 Final Examinations

In 2007, most sub-parts of (a) relied on successful completion of earlier sub-parts while in 2004 this was not so. Again in 2007, for part (b) of this question every sub-part related to previous parts while in 2004 sub-part (v) of part (b) could be solved without any reference to previous sub-parts. Sub-part (i) of part (b) in 2004 needed more calculation in comparison with the similar sub-part (iii) of part (a) in 2007. An added complication was the typographical error in 2007: to answer sub-part (vi) of part (a), students were asked to use their answer to sub-part (iv) when sub-part (iii) was intended. This should not have been a source of substantial confusion.

Question 2: Functions and Limits

The degree of difficulty on the topics of functions and limits remained the same or perhaps might be slightly higher in 2007 than in 2004. In 2007, question 2 part (h) sub-part (iii) had a question on 'differentiation of inverse of a trigonometric function' which would have been better classified as part of question 4 on 'differentiation', 'integration' and 'polar coordinates' (Figure 6.4).

2004

Question 2 (*Use a separate book for your answers to Question 2*)

(a) Simplify $\frac{\sqrt{10}}{\sqrt{110}}$.

(b) Solve for all possible values of x if $\cos 3x = -\frac{1}{2}$.

(c) Find the *exact* value of $\cos y$ if $y = \operatorname{arccot} 3$ and $0 \leq y \leq \frac{\pi}{2}$.

(d) If $f(w) = 2w^2$ and $g(y) = \frac{1}{\sqrt{1+y^2}}$ find $f(g(x))$ and $g(f(3))$.

(e) Find the domain of the function $f(x) = \frac{2x-3}{x^2-4}$.

(f) Evaluate the following limits, if they exist.

(i) $\lim_{x \to 0} \cos x$.

(ii) $\lim_{x \to 3} \frac{x^4 - 9}{x^2 - 3}$.

(iii) $\lim_{x \to -\infty} \frac{2004x^3 - 2001}{2004x^5 + 2005}$.

(iv) $\lim_{x \to \infty} \frac{19x^3 + 18x}{21x^3 - 35}$.

(g) (i) Is $g(x) = \frac{1}{4x}$ the inverse of the function $f(x) = 4x$? You **must** justify your answer.

(ii) Does the function $f(x) = \frac{3x}{x-2}$ have an inverse? You **must** justify your answer. If it does, find the domain and range of the inverse function $f^{-1}(x)$.

2007

Question 2 (*Use a separate book for your answers to Question 2. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) Simplify $\sqrt{27}\sqrt{3}$

(b) Factorise the following quadratic equation

$$y(x) = 2x^2 + x - 1.$$

(c) Sketch the graph of the function

$$xy = 4.$$

(d) Express the following as simply as possible

$$6x^3y^{-2} \times \frac{1}{24}x^{-5}y^4.$$

(e) $n!$ is the number of ways in which it is possible to arrange n objects.

Let's suppose that it takes fifteen seconds to go from one arrangement to another. Then it takes $2! \times 15 = 30$ seconds to view all the arrangements of two objects and $3! \times 15 = 90$, seconds to view all the arrangements of three objects.

How long does it take to take to view all the arrangements of ten objects? (convert your answer to days).

(f) Given that $h(-0.5) = 0$ determine the zeros of the function

$$h(x) = 2x^3 - 3x^2 + 0.5.$$

(g) (i) Evaluate the following limit if it exists

$$\lim_{x \to 0} (x-2)(x-3).$$

(ii) Give an example of functions f and g such that the following hold.

$$\lim_{x \to 0} f(x) = 0, \qquad \lim_{x \to 0} g(x) = 0, \qquad \text{and} \qquad \lim_{x \to 0} \frac{f(x)}{g(x)} \qquad \text{does not exist.}$$

(iii) Evaluate the following limit if it exists

$$\lim_{x \to -\infty} \frac{2x^2 + 3x + 4}{5x^2 + 4x + 3}.$$

(h) (i) If $\sinh x = 4$, write down the *exact* value of $\cosh x$.

(ii) Does the function $f(x) = x^2 - 2x - 3$ defined on the domain $\mathbb{R}$ have an inverse? If so, find the inverse function together with its domain, range and graph. If not, *justify* your answer.

(iii) Differentiate the function $y = \cos^{-1}(x^2 + x)$.

Figure 6.4 Question 2 in the 2004 and 2007 Final Examinations

Questions 3: Vectors

The degree of difficulty is thought to be similar for this question in 2004 and 2007, although the number of questions in 2007 was less than in 2004. While this might suggest that students had less time and therefore possibly the task on 'vectors' was harder in 2004.

In 2004, an examination of part (b) of this question showed that if students could not answer sub-parts (i) and (ii), they could not proceed to sub-parts (iii) and (iv), while in 2007 students could solve sub-part (iii) of (b) without any need for solutions of previous parts (Figure 6.5). This need for reliance on previous answers would have created more difficulty for some students in 2004.

In an interview with the lecturer of the 'vector' topic, he commented that 'every important concept in vector geometry was tested in 2007'.

2004

Question 3 (*Use a separate book for your answers to Question 3.*)

(a) Let $\underset{\sim}{a} = (1, -1, 3)$, $\underset{\sim}{b} = (4, -2, 1)$ and $\underset{\sim}{c} = (2, 1, -6)$.

(i) Find the unit vector of $\underset{\sim}{a}$ and $\sqrt{11}\underset{\sim}{a}$.

(ii) Determine if the vectors $\underset{\sim}{b}$ and $\underset{\sim}{c}$ are perpendicular.

(iii) Determine the direction angles, α, β and γ of $\underset{\sim}{c}$.

(iv) Find the component of $\underset{\sim}{a}$ on $\underset{\sim}{b}$ and that of $\underset{\sim}{a}$ on $-\underset{\sim}{b}$.

(v) Find the projection of $\underset{\sim}{a}$ on $\underset{\sim}{b}$ and that of $\underset{\sim}{a}$ on $-\underset{\sim}{b}$.

(b) (i) Find the equation of the line, $\mathcal{L}_1$, passing through the points $(2, 1, -1)$ and $(0, -1, 2)$.

(ii) Find the equation of the line, $\mathcal{L}_2$, passing through the point $(1, -1, 2)$ and parallel to $\underset{\sim}{a} = (-1, 1, 2)$.

(iii) Determine whether the lines $\mathcal{L}_1$ and $\mathcal{L}_2$, found in parts (b)(i) and (b)(ii) respectively, intersect, are parallel or are skew.
If the lines intersect, find the point of intersection. If the lines are skew, find the distance between them.

(iv) The equation of the line $\mathcal{L}_3$ is given by

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} -2 \\ -3 \\ 5 \end{pmatrix} + \begin{pmatrix} 2 \\ 0 \\ 1 \end{pmatrix} t.$$

Find the point of intersection between the lines $\mathcal{L}_1$, found in part (b)(i), and $\mathcal{L}_3$.

(c) (i) Find an equation, in vector parametric form, representing the plane $\mathcal{P}_1$ passing through the points $(1, -1, 3)$, $(2, -1, -2)$ and $(2, 3, -3)$.

(ii) Show that the linear form of the equation representing $\mathcal{P}_1$, found in part (c)(i), is given by

$$20x + y + 4z = 31.$$

(iii) Let the linear form of the equation representing the plane $\mathcal{P}_2$ be given by

$$2x - 3y + z - 3 = 0.$$

Determine whether the planes $\mathcal{P}_1$, found in part (c)(i), and $\mathcal{P}_2$ intersect or are parallel. If the two planes intersect, find the equation of the intersection line. If the two planes are parallel, find the distance between them.

(iv) Is the point $(1, 1, 1)$ on the plane $\mathcal{P}_2$? Give reasons for your answer.

2007

Question 3 (*Use a separate book for your answers to Question 3. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) Let $\vec{a} = (-1, 2, 2)$, $\vec{b} = (-3, 0, 4)$ and $\vec{c} = (4, 1, 3)$.

(i) Find the unit vector of $\vec{a}$ and $3\vec{a}$.

(ii) Determine if vectors $\vec{b}$ and $\vec{c}$ are perpendicular.

(iii) Find the projection of $\vec{a}$ on $\vec{b}$ and that of $\vec{a}$ on $-2\vec{b}$.

(b) (i) Find the vector parametric equation of the line $\mathcal{L}_1$ passing through the points $P(3, -1, 0)$ and $Q(1, -2, 1)$.

(ii) Given the line $\mathcal{L}$ defined by

$$\mathcal{L}: \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 2 \\ 1 \end{pmatrix} + \begin{pmatrix} -1 \\ 2 \\ 1 \end{pmatrix} s,$$

determine if the lines $\mathcal{L}$ and $\mathcal{L}_1$ intersect, are parallel or are skew, where $\mathcal{L}_1$ is the line found in (b)(i).

(iii) For the line $\mathcal{L}$ given in part (b)(ii), find the distance between $\mathcal{L}$ and the point $R(2, 1, 1)$.

(c) (i) Consider the three points $A(1, 1, 1)$, $B(2, -1, -2)$ and $C(3, -1, 2)$. Find $\overrightarrow{AB}$, $\overrightarrow{AC}$ and $\overrightarrow{AB} \times \overrightarrow{AC}$.

(ii) Using (c)(i), represent the plane $\mathcal{P}_1$ that passes through the points $A(1, 1, 1)$, $B(2, -1, -2)$ and $C(3, -1, 2)$ in vector parametric form.

(iii) Using (c)(i), show that the linear form of the equation representing $\mathcal{P}_1$, found in part (c)(ii), is given by

$$8x + 7y - 2z = 13.$$

Figure 6.5 Question 3 in the 2004 and 2007 Final Examinations

Question 4: Differentiation, Integration and Polar Coordinates

The degree of difficulty on this question might be slightly higher in 2007 because questions on ‘differentiation’ such as sub-part (v) of part (a) and also sub-part (v) of part (e) included a mix of ‘integrals’ and ‘differentiation’ and this involves more knowledge and skills. There was no question like this in 2004 (Figure 6.6).

2004

Question 4 (*Use a separate book for your answers to Question 4.*)

(a) Differentiate the following functions with respect to x, showing all your working.

(i) $x + x^3$

(ii) $\sin^2 x$

(iii) $\dfrac{\cosh x}{2 + \sinh x}$

(iv) $-\cos(x^2)$

(b) If y is given implicitly by the equation $y(x+1) - y^2 = \tan x$ find $\dfrac{dy}{dx}$ in terms of x and y.

(c) A curve is defined by the parametric equaticn $x(t) = t^2$ and $y(t) = e^t$.
Calculate $\dfrac{dy}{dx}$ and $\dfrac{d^2y}{dx^2}$.

(d) (i) Plot the following points, given in polar form

$A\left(3, \frac{\pi}{3}\right)$, $B\left(-3, \frac{4\pi}{3}\right)$, $C\left(3, \frac{-\pi}{3}\right)$.

(ii) Express the polar equation $r = \dfrac{6}{3\cos\theta + 2\sin\theta}$ in Cartesian coordinates.

(e) Evaluate the following integrals.

(i) $\int (4 + 7x - \cos x)\,dx$

(ii) $\int_1^{e^2} \frac{1}{x}dx$

(iii) $\int e^{18x} \sin(4x)\,dx$

(iv) $\int (7 + e^x)\sqrt{e^x + 7x}\,dx$

(v) $\int \dfrac{\cosh x}{5 + \sinh x}dx$

2007

Question 4 (*Use a separate book for your answers to Question 4. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) (i) Differentiate the function $y = \frac{1}{5}\left(7x^3 - \frac{1}{2}x^2 + 2x - 3\right)$ with respect to x

(ii) Differentiate the function $y = x\tan x$ with respect to x.

(iii) By writing $\operatorname{sech} x$ as $(\cosh x)^{-1}$ show that

$$\frac{d}{dx}(\operatorname{sech} x) = -\operatorname{sech} x \tanh x$$

(iv) Differentiate the function $y = \cos(\sin x)$ with respect to x.

(v) Differentiate the function $y = x^{\sin x}$.

(b) Find $\dfrac{d^2y}{dx^2}$ if $\dfrac{dy}{dx} = \dfrac{x + \sin x}{2y - \sin y}$.

(c) A curve is defined by the parametric equation $x(t) = t\cos(t)$ and $y(t) = \sin(t)$. Calculate $\dfrac{dy}{dx}$ and $\dfrac{d^2y}{dx^2}$.

(d) (i) Find the value(s) of r when $\theta = \dfrac{6.5\pi}{12}$ if $r = 5\cos 3\theta$.

(ii) Using the polar graph paper provided at the end of the exam paper sketch the function $r = 5\cos 3\theta$, $0 \le \theta \le 2\pi$. The following set of values may be useful

θ	$\frac{0\pi}{12}$	$\frac{1\pi}{12}$	$\frac{2\pi}{12}$	$\frac{3\pi}{12}$	$\frac{4\pi}{12}$	$\frac{5\pi}{12}$	$\frac{6\pi}{12}$	$\frac{7\pi}{12}$	$\frac{8\pi}{12}$	$\frac{9\pi}{12}$	$\frac{10\pi}{12}$	$\frac{11\pi}{12}$	$\frac{12\pi}{12}$	$\frac{13\pi}{12}$
r	5	3.5	0	-3.5	-5	-3.5	0	3.5	5	3.5	0	-3.5	-5	-3.5
θ	$\frac{14\pi}{12}$	$\frac{15\pi}{12}$	$\frac{16\pi}{12}$	$\frac{17\pi}{12}$	$\frac{18\pi}{12}$	$\frac{19\pi}{12}$	$\frac{20\pi}{12}$	$\frac{21\pi}{12}$	$\frac{22\pi}{12}$	$\frac{23\pi}{12}$	$\frac{24\pi}{12}$			
r	0	3.5	5	3.5	0	-3.5	-5	-3.5	0	3.5	5			

You should also use your answer to (d)(i).

(e) Evaluate the following integrals.

(i) $\int_2^3 3e^{2x}\,dx$

(ii) $\int e^{18x}\sin 4x\,dx$

(iii) $\int \dfrac{dx}{x\sqrt{19x + 6}}$

(iv) $\int_2^4 (2x - 3)^5\,dx$

(v) $\dfrac{d}{dx}\int_{75}^{\tan x} t^2 \sin t\,dt$

Figure 6.6 Question 4 in the 2004 and 2007 Final Examinations

6.5.2 Continuous Assessment

Continuous assessment was used throughout the teaching session in the form of assignments and quizzes. As mentioned in Chapter 3, regular students were given five assignments, once every fortnight, and the engineering opportunity students were given eleven assignments, once every week except weeks 12 and 13.

The tutors set the assignments and quizzes, so within each year different tutorial groups received different assignments and quiz questions. The assignment questions were set so as to be similar to those given in the tutorial sheet, and these related to specific sections in the lecture notes. There were four quizzes, occurring in weeks 3, 5, 7 and 11. The quiz items were chosen from a bank of items (five questions for each quiz) based on the work for the previous fortnight. In drawing a comparison between the two cohorts, it is assumed that the difficulty level is comparable. It is unlikely that 4-5 tutors setting assessment would have all had a bias that favoured easier quizzes and easier assignments in 2007 compared to 2004.

The means and standard deviations for assignments in the cohorts are presented in Table 6.8. A Levene's test for the equality of variances revealed significant differences in variance between student assignments in 2004 and 2007 ($F = 8.09$, $p = 0.005$). An independent t-test analysing the assignments between the two cohorts found a significant difference ($t_{456} = 2.80$, $p = 0.005$) between students in 2004 with a mean out 7.3 out of 10, compared to a mean of 8.0 for students in 2007 (Table 6.8).

Table 6.8 Assignments in 2004 and 2007

Year	N	Mean	S.D.
2004	215	7.29	3.01
2007	243	8.03	2.60

The means and standard deviations for quizzes in 2004 and 2007 are presented in Table 6.9. A Levene's test for the equality of variances revealed no significant differences in variance between students quizzes in 2004 and 2007 ($F = 2.99$, $p = 0.08$). An independent t-test analysing the quizzes between the two cohorts found a significant difference ($t_{456} = 3.49$, $p = 0.001$) between students in 2004 with a mean of 4.8 out of 10, compared to the students in 2007 with a mean of 5.4 (Table 6.9).

Table 6.9 Quizzes in 2004 and 2007

Year	N	Mean	S.D.
2004	215	4.75	2.17
2007	243	5.43	2.00

6.6 Final Outcomes

It was hoped that the video resources would lead to an improvement in performance. When the Mid-Session Test revealed no such improvement, it cast some doubt as to the efficiency of the resources. Examination of all evidence, including the weaker evidence provided by assessment (which was similar but not identical), suggests that the results for the Mid-Session Test are anomalous (Figure 6.7). As previously suggested, this could be due to the test being poorly timed in relation to lectures adequately covering the topics. Except for the Mid-Session Test and the baseline measurement of skills in week 1, the students with access to the video resources outperformed those who did not.

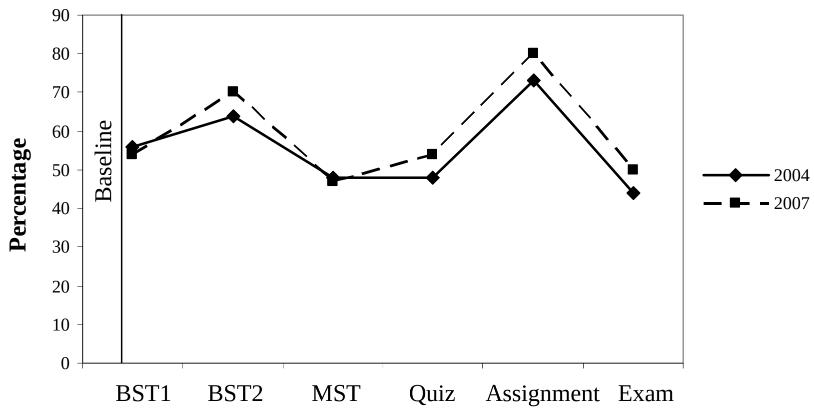


Figure 6.7 Student Performance on Assessment Tasks in 2004 and 2007

To complete the analysis of the cohorts and associated performance, regression models were developed to predict examination marks and final marks. Earlier work, conducted on 2006 data, had indicated that the outcomes for students who used resources was associated with the baseline skills as measured by BST1 whereas there was no association for those who did not use the resources. As can be seen in Figure 6.7, the performance profile in 2004 and 2007 was the same except for the baseline and the MST, suggesting that there was an interaction between assessment and year.

To predict both examination mark and final mark, the variables Basic Skills Test 1 (BST1), Basic Skills Test 2 (BST2), best score (BST2 - BST1), the Mid-Session Test (MST), assignment mark, quiz mark and year were used as predictors. All the interaction terms formed from each of the assessments marks and year together with all interaction terms formed by combining the separate assessment tasks with entry level skills as measured by Basic Skills Test 1 were included as predictors.

Steps undertaken for analyses predicting examination marks and final marks were:

1. The analysis of the examination marks and final marks commenced with a step-wise multiple regression using a forward selection of variable to identify the best model. First the most significant variable is included in the model and then successive significant variables are introduced one at a time until no more are significant.
2. The final model was formed by entering all significant terms as found by the forward selection process and in addition including any term that was part of a significant interaction term.
3. An examination of the correlations between all predictor and interaction terms was used to examine the impact of colinearity.
4. Regression diagnostics were used to check that the assumptions underlying the model had been met. This included a check on the normality of errors through the use of a P-P plot and a check on homogeneity of variance and linearity of the relationship with a plot of standardised residuals against standardised predicted values.

6.6.1 Prediction of Examination Marks

The best model ($F_{5,\ 624} = 78.92$, $p < 0.001$) using a forward selection approach for predicting the examination marks included the significant predictors:

- assignment ($t = 7.36$, $p < 0.001$),
- BST2 ($t = 5.34$, $p < 0.001$),
- MST ($t = 2.97$, $p = 0.003$),
- quiz ($t = 2.74$, $p = 0.006$) and
- the significant interaction term MST * year ($t = 2.42$, $p = 0.016$).

Because the above model included MST and MST * year, but not year, the year term was then forced to enter the model. This produces a model which is more simply interpreted than one omitting ‘year’. The final model summary, ANOVA and coefficient are shown in Table 6.10.

The model created by the forced entry of year for predicting examination mark explains, as measured by the adjusted R square of 0.38, which is explaining 38% of the variation in the examination marks. The final model was described by the equation:

$$\text{Expected (Examination mark)} = -4.34 + 0.93 * \text{BST2} + 0.66 * \text{MST} + 1.95 * \text{assignment} - 0.62 * \text{year} + 1.02 * \text{quiz} + 0.13 * \text{MST} * \text{year}$$

Forcing the entry of the components of the interaction term may also lead to some previously significant terms appearing insignificant, as occurred here (Table 6.10). However, in order to explain the impact of the significant interaction, the terms that form the interaction are required in the model.

Table 6.10 Regression Output for Examination Mark

Model Summary [b]

Model	R	R Square	Adjusted R Square
1	0.62 [a]	0.38	0.38

a Predictors: (Constant), MST * Year, Assignment, Mark in BST2 out of 20, Year, Quiz, Mark in MST out of 25
b Dependent Variable: Mark in Exam

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	101179.23	6	16863.21	75.40	0.000 [a]
	Residual	163720.76	732	223.66		
	Total	264899.99	738			

a Predictors: (Constant), MST * Year, Assignment, Mark in BST2 out of 20, Year, Quiz, Mark in MST out of 25
b Dependent Variable: Mark in Exam

Coefficients [a]

		Unstandardised Coefficients		Standardised Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	– 4.34	9.91		– 0.44	0.661
	Mark in BST2 out of 20	0.93	0.17	0.19	5.51	0.000
	Mark in MST out of 25	0.66	0.68	0.14	0.96	0.338
	Assignment	1.95	0.28	0.25	7.08	0.000
	Year	– 0.62	1.72	– 0.04	– 0.36	0.719
	Quiz	1.02	0.38	0.10	2.70	0.007
	MST * Year	0.13	0.12	0.20	1.13	0.259

a Dependent Variable: Mark in Exam

The impact of the predictors that are not part of an interaction can be determined by examining the unstandardised coefficients. For an increase in the variable of one, the predicted final mark increases by the value of the coefficient. Therefore, for example, if Basic Skills Test 2 increases by one mark the predicted examination mark would increase by 0.93. For negative coefficients, an increase of one corresponds to a decrease in the predicted examination mark.

The impact of the interaction term can be demonstrated by evaluating the model for both years, and varying the set of MST scores, while holding all other predictor variables constant. To show the impact of the interaction term, the predicted examination marks were calculated for students in 2004 and 2007 (coded 4 and 7) with the assignment mark (6), BST2 mark (12), quiz mark (5), and with four different values for the MST mark (6, 10, 14 and 18). The predicted mark for each year for the MST marks is plotted in Figure 6.8. It can be seen that as the MST mark increases, the predicted examination marks increases more in 2007 than it does in 2004.

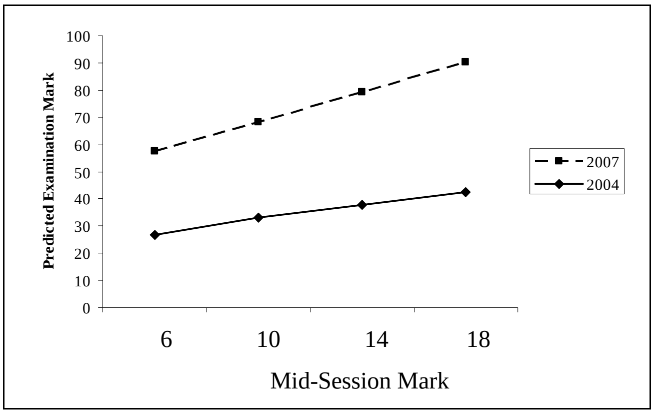


Figure 6.8 Predicted Examination Mark

6.6.2 Predictions of Final Marks

The best model for predicting final marks ($F_{4,\,623}$ = 251.10, p < 0.001) with an adjusted R square of 0.62, that is explaining 62% of the variation in final marks included the significant predictors MST (t = 14.04, p < 0.001), BST2 (t = 7.48, p < 0.001), assignments (t = 11.63, p < 0.001), and the interaction term quiz * year (t = 5.58, p < 0.001). The model created by the additional forced entry of the variables quiz and year explained 61% of the variation in final mark. The final model summary, ANOVA and coefficient are shown in Table 6.11.

The final model was described by the equation:

$$\text{Expected (Final mark)} = -11.05 + 0.90 * \text{BST2} + 1.64 * \text{MST} + 2.03 * \text{assignment} + 1.12 * \text{year} + 1.64 * \text{quiz} - 0.05 * \text{quiz} * \text{year}$$

Table 6.11 Regression Output for Final Mark

Model Summary [b]

Model	R	R Square	Adjusted R Square
1	0.78 [a]	0.62	0.61

a Predictors: (Constant), Quiz * Year, Mark in MST out of 25, Assignment, Mark in BST2 out of 20, Year, Quiz
b Dependent Variable: Final Mark

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	121266.61	6	20211.10	193.83	0.000 [a]
	Residual	76016.43	729	104.28		
	Total	197283.04	735			

a Predictors: (Constant), Quiz * Year, Mark in MST out of 25, Assignment, Mark in BST2 out of 20, Year, Quiz
b Dependent Variable: Final Mark

Coefficients [a]

		Unstandardised Coefficients		Standardised Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	– 11.05	5.67		– 1.95	0.052
	Mark in BST2 out of 20	0.90	0.12	0.21	7.78	0.000
	Mark in MST out of 25	1.64	0.11	0.41	15.02	0.000
	Assignment	2.03	0.19	0.30	10.67	0.000
	Year	1.12	1.00	0.08	1.11	0.266
	Quiz	1.64	1.06	0.19	1.54	0.124
	Quiz * Year	– 0.05	0.18	– 0.04	– 0.28	0.779

a Dependent Variable: Final Mark

The impact of the interaction term can be demonstrated by evaluating the model for both years, and varying the set of quiz scores, while holding all other predictor variables constant. To show the impact of the interaction term, the predicted final marks were calculated for students in 2004 and 2007 (coded 4 and 7) with the assignment mark (6), BST2 mark (12), MST mark (12) and with four different values for the quiz mark (1, 3, 7 and 9). The predicted marks for the quiz for each year are plotted in Figure 6.9. As the quiz mark increases, the predicted final mark increases more in 2007 than it does in 2004.

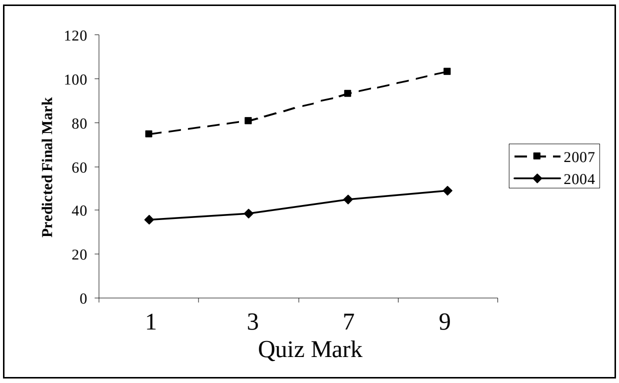


Figure 6.9 Predicted Final Mark for Quiz Mark

An inspection of the correlations between all interaction terms formed by year and BST1 found that all, except MST minus BST1, were correlated with the final marks. Therefore, other models which are nearly as effective can be used to predict the final mark. For example, substituting the interaction term quiz * year with MST * year, as seen in Figure 6.10, suggested interaction between MST and year results in the model.

$$\text{Expected (Final mark)} = -4.28 + 0.90 * \text{BST2} + 1.25 * \text{MST} + 2.05 * \text{assignment}$$
$$- 0.11 * \text{year} + 1.35 * \text{quiz} + 0.07 * \text{MST} * \text{year}$$

This model also explains 61% of the variation in the final mark as measured by the adjusted R square. To show the impact of the interaction term, the predicted final marks were calculated for students in 2004 and 2007 (coded 4 and 7) with the BST2 mark (12), assignment mark (6), quiz mark (5) and with four different values for the MST mark (6, 10, 14 and 18). The predicted final marks for each year for the MST are plotted in Figure 6.10. It can be seen that, as the MST mark increases, the predicted final mark increases more in 2007 than it does in 2004.

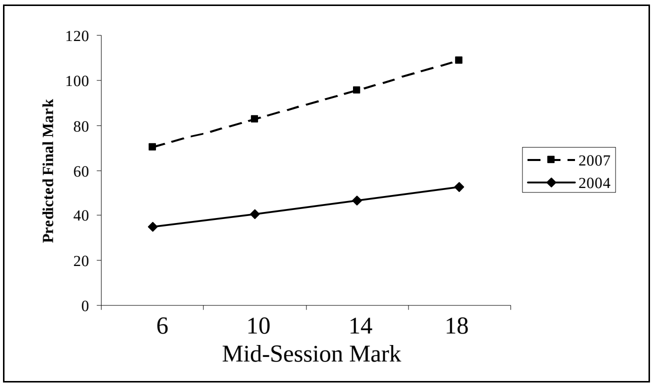


Figure 6.10 Predicted Final Mark for the Mid-Session Test Mark

6.7 Results of the Change Evaluation

Data from the change evaluation in 2005-2007 were used to evaluate the video learning resources in the context of other learning resources and to compare students' confidence in different topic areas.

6.7.1 Changes in Learning and Understanding

During the developmental phase, explained in Chapter 5, students had indicated that the video resources had helped them to learn and understand. However, while examination of the student comments suggested that students were predominantly appreciating the clarification of the algorithmic steps in solutions, it was often not clear as to what students had meant when they referred to 'understanding'. In order to clarify this, in 2007 they were asked to identify what they gained from the video resources (Appendix 13). They were provided a list of options developed from the earlier formative evaluation in 2006 (Table 6.12). The responses to the question confirmed that the knowledge of how to complete the steps was the most often perceived gain. However, over half the respondents indicated that they had gained in other ways; from improved retention (52%) to being able to refresh theory, rules and definitions (62%) (Table 6.12). A substantial proportion of students (40-50%) found the video resources provided alternative ways to lay out work, motivation and ways to self-check.

Table 6.12 Rank Ordering of Aspects of Understanding and Problem Solving Gained from Using Video Resources in 2007*

Did you gain?	Responding N	Confident doing this	Confident & moderately confident
How to complete the steps involved	69	17.4	72.5
Refresher of theory/rules/definitions	68	11.8	61.8
More confidence	68	10.3	60.3
Understanding of the concepts involved	68	13.2	58.8
Ways to distinguish what type of problem you were doing	68	22.1	57.4
New way to start problems	68	16.2	55.9
Skills in reading & writing mathematics	68	11.8	54.4
Alternative approaches to completion	68	11.8	53.0
Retention (easier to remember concepts and procedures)	68	16.2	51.5
Ways to self-check	68	13.2	48.5
Motivation	68	8.8	44.1
Alternative ways to layout work	67	9.0	43.3

*Approximately 32.7% of the 101 students did not respond to this question (n = 33) including 18 students who did not answer any questions on the second page. Indeed 22% of the students had indicated that they rarely used use the resources (n = 22). The percentages in the table are of those who responded to the question.

6.7.2 Changes in Perceptions of the Usefulness of Learning Resources

In Chapter 5, the change evaluation was described as an end-of-session survey that evaluated all learning resources available to students in MATH141. The primary objective of the change evaluation is to obtain a ranking of the usefulness of the learning resources in terms of helping students learn and understand mathematics. Students were asked to rate each of the learning resources in terms of their usefulness. Students' comments and a ranking of the usefulness of the learning resources were then used to help target what resources, if developed, had the most scope for improving understanding (Table 6.13). The primary learning resources were considered to be those traditionally provided as a part of a subject: the teaching, lectures and tutorials and the associated activities and the assessment. Secondary learning resources are those designed to support the primary path to subject completion. In MATH141 the first lecture strand includes the topics: 'fundamentals', 'differentiation', 'polar coordinates' and 'integration'. The second lecture strand includes the topics 'matrices and determinants' and the third one covers 'vector geometry'.

Table 6.13 Usefulness of Resources in Helping Students Learn and Understand Mathematics Rank Order from Highest to Lowest in 2007

	Useful 2005	Useful 2006	Useful 2007†	2007-2006	
	N = 45 %	N = 83 %	N = 101 %	Z	Sig.
Lectures fundamentals, differentiation, polar coordinates and integration	95.6	93.8	93.1	– 0.20	
Tutor	86.7	82.6	93.1	2.21	*
Tutorial classes	88.9	83.8	90.1	1.27	
Assessment: Assignments	91.1	81.5	89.1	1.46	
Other work done in your own time	-	75.3	86.2	1.86	
Tutorial tasks	91.1	87.7	86.1	– 0.30	
Tutorial solutions	73.3	76.6	78.2	0.29	
Assessment: Mid-Session Test	84.4	81.5	76.0	– 0.89	
Assessment: Quizzes	-	-	65.0	-	
Fill-in lecture notes	-	-	63.0	-	
Lectures matrices and determinants	-	77.8	59.6	– 2.60	**
Basic Skills Tests	-	64.2	58.6	– 0.77	
Lectures vector geometry	-	53.8	57.0	0.44	

* $p < 0.05$, ** $p < 0.01$

† Percentage based on 98 to 101 respondents

From the analysis of the change evaluation in 2007, the lectures for the topics ‘fundamentals’, ‘differentiation’, ‘polar coordinates’ and ‘integration’ are seen as the most important in contributing to student learning and understanding. For the topics ‘matrices and determinants’, and ‘vector geometry’, the best scope for improvement appears to be in the lectures (Table 6.13) together with replacement of the Basic Skills Tests, and from the 2006 data, an improvement in lecture notes. Quizzes and the Basic Skills Tests are rated low in terms of their contribution to learning compared to the assignments, which 89% of students consider useful in helping them to learn and understand. In an absolute sense, the QUALITY101 working party would seek to have 90% or more of students rating the primary resources as moderately or extremely useful (Porter 2006a).

It is difficult to compare the secondary or support learning resources, precisely because they were not a core component of the subject. They were supplementary to the primary resources. One of the popular secondary learning resources was the PASS (Peer Assisted Student Study) program. The video resources were not rated as well as the PASS programs (Table 6.14) but were equivalent in ranking to the primary resources: lectures 2 and 3 and the Basic Skills Tests, in terms of contributing to learning and understanding (Table 6.13). Table 6.15 shows that in 2007, 60% of students attended ten or more PASS sessions in the thirteen-week term, usually on a weekly basis.

Table 6.14 Support Learning Resources Rank Ordered from Highest to Lowest in 2007 Based on all Students Responding

	Useful 2005	Useful 2006	Useful 2007	2007-2006	
	N = 45 %	N = 83 %	N = 101 %	Z	Sig.
PASS program sessions	89.0	77.0	81.0	– 1.56	ns
Fill-in lecture notes	-	65.0	63.0	– 0.67	ns
Video resources	-	56.9	55.4	0.28	ns
WebCT/ eLearning forum	-	20.1	32.7	0.20	ns

Table 6.15 PASS Program Sessions Attendance

	2006	2007
	N = 83 %	N = 101 %
0	18.1	10.9
1-3	13.3	7.9
4-6	1.2	12.9
7-9	13.3	6.9
10-13	34.9	50.5
14+	19.3	8.9
No response	-	2.0
Total	100.0	100.0

However, students have had access to the PASS program in previous years and there is less scope to improve in this area. Certainly, the added benefit of video resources appears to have contributed to improved performance.

6.7.3 Changes in Perceived Confidence with Topics

Over the three years 2005, 2006 and 2007, students were asked to indicate how confident they were in relation to each of the major topics. Possible ratings were: ‘not at all confident’, ‘might have a little difficulty’, ‘moderately confident’ and ‘could do this’. Student confidence has been strongly linked to their ability to do the work in other disciplines. Morris, Porter and Griffiths (2005) found the level of student confidence was strongly linked to the ranking of the mean exam mark for the topics, supporting the contention that students collectively appear to be aware of when they have learned a topic and when they have not.

The rankings of students’ confidence can be used to identify where additional learning resources (assessment, examples, improved lecture notes, video resources) may be of benefit. In making these decisions, an assessment of the importance of the topic should be considered. Is the topic sufficiently important that it will be assessed in assignments and on the final examination? The aim here is not to teach to the test but to be aware of what content and skills in the subject are considered to be the highest priority.

The rankings can also be used to examine differences in confidence between the two years (Table 6.16) when:

- In 2006, video resources were available for the fundamental topics and
- In 2007, video resources were available for all topics.

Table 6.16 Student Confidence Responses for Specific Topics†

	Moderate confidence & could do 2006		**Moderate confidence & could do 2007**		**2007-2006**	
	N = 83	**%**	**N = 101**	**%**	**Z**	**Sig.**
Fundamentals (Skills)	70	84.4	91	90.1	1.18	
Differentiation	67	80.7	84	83.2	0.43	
Polar Coordinates	49	59.1	75	74.2	2.19	*
Integration	54	65.1	63	62.4	– 0.38	
Matrices and Determinants	53	63.9	61	60.4	– 0.48	
Vectors Geometry	34	40.9	53	52.5	1.55	

† Percentages based the entire sample including those who did not respond
* $p < 0.05$

Confidence had risen significantly in ‘polar coordinates’ from 2006 (partial video resources) to 2007 (full set of video resources) ($Z = 2.19$, $p < 0.05$). This is difficult to explain from the resources, however, because the number of video resources only increased from three in 2006 to four in 2007. There was no appreciable increase in confidence for other topic areas, despite increases in resources.

Because the development and exploration of what learning resources students needed had evolved over time, in 2007 the topics were split and students were asked to indicate how confident they were with several sub-topics. This is presented in Table 6.17.

Table 6.17 Identifying Sub-topics Where Students Feel Competent*

	Moderate confidence & could do 2007	
	N	**%**
Vectors, Dot Product and Cross Product	65	64.4
Matrix Notation, Operations and Row Echelon Form	59	58.4
Straight Lines and Planes in Space	44	43.6
Inverse, Elementary Matrices, Determinants and Eigenvalues/Vectors	43	42.6

* Percentages based on the entire sample including those who did not respond

The resources developed for the class of 2007 were based upon a list of topics circled by students in the change evaluation survey conducted in week 12, 2006. In 2007, the survey contained an open-ended question asking if there were any additional video resources required. Five per cent of students specified that more was needed on all topics. Still more students, 10% (n = 10), responded wanting: ‘more examples’, ‘as many as possible’, ‘harder examples’, ‘exam questions’ and ‘complex questions’. Additional requests included specified topics. Six per cent (n = 6) was for resources ‘on the application of matrices to systems of differential equations’ and 5% (n = 5) ‘vectors’. One request each was made for ‘implicit differentiation’, ‘parametric differentiation’, ‘determinants’, ‘methods of integration’ and ‘quadratic equations’. Six per cent of students (n = 6) also requested more ‘helpful shortcuts’, ‘theory refreshers’ or ‘definitions’.

6.7.4 Identifying Students’ Preferences for Learning Resources

The QUALITY101 working party has found differences in preferences for learning resources between male and female students and between international and domestic students. This latter, of course, may be due to difficulties with the English language, but further investigation in regard to gender or to language background is beyond the scope of this thesis. For example, international students have been found to favour eduStream (recordings of lectures combined with PowerPoint slides), multiple choice questions and worked solutions as resources. Domestic students have shown a greater preference for the PASS program (Porter 2004). There are insufficient data to make a meaningful comparison. Ninety per cent of the respondents were male (n = 62) and 10% female (n = 7). Thirty-two per cent of students did not respond to the question regarding gender (n =

32). Similarly, 84% of respondents had English as a first language (n = 58) and 16% did not (n = 11). Thirty-two per cent did not respond to the question (n = 32).

6.8 Focusing on 2008

Based on student comments as to 'How best can MATH141 be improved?' the greatest scope for improvement is in the following areas:

- improving the lecture strand for the topics 'matrices and determinants' and 'vector geometry',
- changing assessment and
- additional resources.

6.8.1 Improving Lectures

Students' comments regarding the usefulness of learning resources revealed a marked difference between one of the sets of lectures and the other two. This is supported by the student ratings (Table 6.13) which rated all the primary learning resources. Lectures for 'matrices and determinants' and lectures for 'vector geometry' were rated as being of least use in helping students learn and understand. While students acknowledged that sometimes they were the ones who behaved badly, they also called for better teaching skills. They wanted more 'class control' and 'better input'. They looked for improvement in speaking skills and the use of the microphone. They also felt that handwritten projector slides could be 'very difficult to read/understand' and commented that lecturers should find 'more interesting ways of lecturing rather than reading'.

The poor lecture strands, as judged by student responses, were the same areas where the students had difficulties. While the students did not rate the lecture strand for 'vectors' highly in terms of usefulness in helping them to learn and understand, by the examination in 2007 there was an improvement in the marks for the 'vector' questions. It is possible that students used the learning resources between the survey and the final exam.

6.8.2 Assessment

Assessment through the use of the Basic Skills Tests was also rated lower than lectures on ‘fundamentals’, ‘differentiation’, ‘polar coordinates’ and ‘integration’ as well as lower than lectures on ‘matrices and determinants’, in terms of helping students learn and understand (Table 6.13). The main lecturer indicated that the Basic Skills Tests are primarily designed to encourage students to work in the first four weeks, rather than as assessment tasks. Nevertheless, students commented in relation to assessment:

> Make the final test worth a little less, say 50% and more marks for quizzes.
>
> Do not have a multiple-choice mid-term as working and understanding is not rewarded, but guesses are.
>
> Make the final exam worth less and assignments worth more.
>
> Give marks on tutorial assignments, instead of just ‘U’ or ‘S’.

The second set of comments was in relation to the nature of the assessment they wanted to undertake. The response was mixed. Some wanted more assignments and suggested increasing to two tests per week while one comment suggested there be ‘no quizzes’.

6.8.3 Learning Resources

The learning resources developed included some video clips of ‘theory refresher’, such as definitions and rules, in addition to worked solutions (Table 4.2). In the research much less attention has been paid to the development of theory refreshers than to the development of worked solutions. By the end of the first teaching session in 2007, however, the students were not requesting more video resources. In terms of improving MATH141, the provision of additional video resources seems less important for this class than it was in 2006.

There are also questions as to whether examples should be extended to include application of the skills in context. Because of how the subject is structured and assessed, contextualised questions are not required. If a greater emphasis were placed on the transfer to other disciplines, contextualised questions would probably be needed, however examining this is beyond the scope of this thesis. Students have requested improvements or additional resources in three main areas. The following is a selection of their comments.

Text and Course Notes

> Better textbook.
>
> Improving sections of course notes, ‘vectors’ and ‘matrices’ where too much info is given and explanations are poor.
>
> Improve the notes. There are lots in mistakes in [the notes].
>
> More fill the spaces work in the text book for matrices and vector geometry.
>
> Better notes.
>
> Improvement in textbooks. e.g. content index and correct exercise numbers in answers.
>
> Complete lecture notes in textbook.

More time

> More one-on-one.
>
> Smaller class size.
>
> More tutorial time.
>
> More tutorials, [we] learn better in tutorials.
>
> Introduce more student and tutor time.

More Examples

> More clear examples.
>
> More video available.
>
> Downloadable exercise sheets.
>
> Go though more worked examples.
>
> More resources of a wider range of questions.

For some, perhaps the rare student, the subject needed ‘less focus on high school skills’, ‘more focus on new skills’, or ‘at least the harder high school skills’.

6.9 Conclusion

In the QUALITY101 report on MATH142 (Porter 2006b) the dominant theme in relation to improving MATH142 had to do with the provision of more resources such as those provided in MATH141 and removing the gaps in lecture notes. Typical comments included:

> Also having the text without gaps would ensure that a student may give their full attention to listening to the lecturer and trying to understand what the lecturer is teaching. It is ridiculous that students are paying big money to sit in a lecture and not be able to learn for the whole time because of the fact that the gaps have to be filled in just so we have a complete set of notes.
>
> … the notes need to be fixed. If the notes have gaps the teachers should teach to this from the start, which they didn't. But even this method is just close passages and you don't really learn maths. The NOTES should be the same as the MATH162 notes, which are detailed and easy to learn from. The notes should also have FULLY WORKED ANSWERS to ALL QUESTIONS in the book including old exam papers (Porter 2006b).

As discussed in Chapter 3, MATH141 had a mix of lecture notes during 2004 and 2007 with and without gaps, leaving out some definitions and examples (Figure 3.2). MATH142 had lecture notes which had gaps in both the definitions and in examples to be worked during lectures. A better model is probably provided by MATH151 which has no gaps in theory, but allows space for examples to be worked in lectures and exercises.

One of the focuses of this chapter was to investigate the effect of the video resources on learning outcomes. This was done by examining changes in performance for two cohorts of students in 2004 with no video resources, and students in 2007 with a complete set of resources. Another focus was to seek what features of learning or understanding have been affected and to recognise how to improve video resources for students in the introductory mathematics subject, MATH141.

Data from 2004 and 2007 showed that students' performance at the baseline, the profile of the best and worst was the same, except for the skill 'arithmetic' (Chapter 3). Students with video resources were found to have improved their performance in all assessment tasks compared to students without resources: Basic Skills Test 2 (t_{390} = 3.14, p = 0.002), assignments (t_{456} = 2.80, p = 0.005), quizzes (t_{456} = 3.49, p = 0.001), examination marks (t_{456} = 3.03, p = 0.003), and final marks (t_{446} = 2.38, p = 0.018), except in the Mid-Session Test (t_{467} = 0.65, p = 0.519). The failure rate fell significantly in 2007 compared to the years between 2000 and 2006 (Z = 2.10, $p < 0.05$). Students' surveys show that although the primary gains have been in algorithmic learning, students believe they have better understanding of concepts.

Looking over all assessment tasks, it would appear that the resources have been effective in improving performance in MATH141. This is supported by the change in students' comments from 2006 to 2007 wherein students expressed less need for resources.

It would appear from the student comments that the supply of video resources only requires minor further development. Approximately 10-15% of students want more resources, sometimes on specified topics, and sometimes in the theory refresher area.

The next chapter reports on a second case study in which another aspect of the use of technology to improve mathematical education is investigated. Specifically, it provides a comparative examination of Real Time Communication technologies such as videoconferencing and Web Conference Applications, with a view to making recommendations for adoption at the institutional level.

Chapter 7

A Comparison of Real Time Communication Technologies for Teaching and Learning

7.1 Introduction

In the first case study, video learning resources were created (Chapter 4) and evaluated (Chapter 5) to address the problem of a mathematical skills deficit in students entering university. The learning resources were accessed by students through a Learning Management System or 'virtual learning environment'. Wilson et al. (2006) described these environments as providing a 'consistent model of integrating a set of tools (forums, quizzes) and data (students, content) within a context of a course or module' (p. 2). These environments are contrasted with other learning environments which are described as Personal Learning Environments (Wilson et al. 2006) or 'participatory Web' (Madden & Fox 2006). Personal Learning Environments are typified by 'peer to peer systems, weblogs, wikis, and social software' (Wilson et al. 2006, p. 1). These approaches, also referred to as 'Web 2.0', appeal to young people (Madden & Fox 2006). They are seen as a basis for informal learning and hence better represent the needs of lifelong learners (Wilson et al. 2006), however, some have expressed concerns about the use of Web 2.0 applications in formal institutions. For example, the Deleting Online Predators Act (DOPA) tries to

> … address the moral panic over sites like MySpace and the perceived 'dangers' they pose to children, by banning the use of commercial social networking websites in US schools and libraries (O΄Hear 2006).

The Act was proposed in the United States Congress in 2006. However, it did not become law (http://www.govtrack.us/congress/bill.xpd?bill=h109-5319) and the huge number of users of social software applications would make their outlawing difficult, if not impossible.

Web 2.0 applications offer a new range of interactions to online learning and the developers of Learning Management Systems (LMSs) either have plans to incorporate them or already have done so. For example, Blackboard has recently begun to incorporate wikis and blogs (http://www.blackboard.com/communities/beyond/) and the open source LMS Moodle has built a range of Web 2.0 modules (http://moodle.org/).

This thesis is not about Web 2.0 technologies in teaching and learning - rather it is about media richness in online communications and content. However, Web 2.0 technologies do have the potential for positive impact on teaching and learning for several reasons. Perhaps the greatest of these stems from the blurring of the boundaries between social networking and educational networking. This in all probability could lead to opportunities for greater authenticity in educational experiences (Wilson 2005). The area of enquiry of Web 2.0 in education is particularly broad and warrants much further work but is outside of the scope of this thesis.

Modern technologies provide new approaches to tertiary education and will be an increasing component of the educational experience in the future. Their use poses a significant challenge to the design and delivery of teaching and learning as many teachers and students are unfamiliar with them in this context. There has been a very rapid expansion in the capability and usage of information and communication technologies (ICTs) in teaching and learning (West 1998). To use them effectively, there is a need to understand how different ICTs can be applied to learning and teaching. Various technologies, such as videoconferencing, Web Conference

Applications (WCAs), Access Grid, Video Chat and Enhanced Video Chat are now available for use in higher education. In this chapter, the technologies are compared with a view to recommending which ones to implement for teaching and learning within the context of the University of Wollongong.

7.2 Methodology

The University of Wollongong had been using videoconferencing for 15 years and the Manager of Learning Facilities and Technologies was of the opinion that it was high time to ascertain if there were other technologies that would be better in terms of efficiency and effectiveness for two-way interactions between students and teachers at a distance (Caladine & Aminifar 2007). The researcher was presented with the opportunity to work with the Manager of Learning Facilities and Technologies, Dr Caladine, to compare a range of technologies that facilitate real-time or synchronous communications. These technologies are referred to as Real Time Communication (RTC) technologies. They were being reviewed for teaching and learning at the University of Wollongong. Dr Caladine worked within the Centre for Educational Development and Interactive Resources (CEDIR) and had the responsibility of recommending, supplying and maintaining systems of learning technologies for institution-wide use.

A methodology similar to an apprenticeship model was adopted. Information was gathered through a number of artefacts. The researcher conducted informal interviews and worked with Dr Caladine on the review of a range of two-way audio and video technologies that were considered to offer more than videoconferences. In addition, the researcher with Dr Caladine, undertook a review of the technologies based on their features, and participated in demonstrations of a number of RTC technologies under review. Further data regarding each technology were gathered from advertising and promotional information.

The purpose of the review was to recommend to the University of Wollongong a single technology or a range of technologies that could be used to replace or complement videoconferences. The aim was to recommend technologies which were more educationally effective than videoconferencing.

From a university teacher's perspective, when a subject is taught at different locations, it is essential that all students be able to interact and discuss the subject. To achieve this, it was believed that the use of shared eWhiteboards and application sharing (Section 7.6) would assist students in understanding the material and collaborating on the problems that they were solving. In addition, if the technologies had a facility to record students' interactions they could be used for other purposes, such as revision of the topics.

7.3 Background

The University of Wollongong has five regional campuses or 'access centres' as well as a main campus. While some of the campuses are relatively close to the main campus, within an hour's drive, others are hours away. The campuses are located at Loftus, Moss Vale, Shoahaven, Batemans Bay and Bega. Since the early 1990s, videoconferencing has been used to teach across campuses, allowing the exchange of the video and audio of participants. This has provided a significant time-saving for students and teachers. Originally, videoconference endpoints were connected via ISDN (Integrated Services Digital Network). These videoconferences have been expensive and not always reliable. An annual ISDN bill of approximately $80,000 was reported, together with frequent disruptions to service (Caladine 2006b). Today, if bandwidth is sufficient, the internet is commonly used to connect videoconference endpoints.

The technologies considered here (Access Grid, Web Conference Applications, videoconferencing, Video Chat and Enhanced Video Chat) rely on dialogue between the connected users, in order for learning and teaching to be considered effective and efficient. Unless the sessions, or 'conferences', are recorded, however, they are ephemeral and not available after the event. Recording of sessions or 'conferences' allows asynchronous and repeat uses for purposes such as revision, assessment and to cover absences, etc.

Videoconferencing is seen as a mature technology for teaching and learning at the University of Wollongong as it has been used for more than 15 years. The staff responsible for the educationally sound use of videoconferencing, however, believed that the enhancement of learning experiences through the addition of other functions not normally found in videoconferences was overdue (Caladine, R. 2007, pers. comm., 22 May). Other technologies such as the Access Grid and Web Conference Applications offer these ‘other functions’, including shared eWhiteboard, presentation sharing, application sharing, and presentation of mathematical symbols as well as the saving of resulting files. These functions enhance synchronous learning and teaching and, when recorded for later use, provide opportunities for asynchronous learning.

In this study, RTC technologies collectively refer to the following technologies: videoconference, Access Grid, Web Conference Applications, Video Chat and Enhanced Video Chat. The main motivation to replace the videoconference with other RTC technologies was that videoconferencing is often limited to discussion between participants and/or short presentations. RTC technologies, on the other hand, offer a wider variety of educational tools, such as eWhiteboards and shared presentations (for example, PowerPoint). Furthermore, Real Time Communication technologies have the potential to increase the efficiency and effectiveness of teaching and learning for a distributed cohort of students. For instance, RTC technologies can unite a teacher based at one location with students at a number of campuses into a synchronous class, providing access between the teacher and the students and a mechanism for students’ interaction between different campuses.

Real Time Communication (RTC) technologies are designed to be used synchronously, however, as mentioned earlier, RTC interactions can be recorded and used asynchronously by students who did not attend the class, or for revision. The files that are recorded for later use are equally helpful for students who are unable to attend lectures through illness or commitments to part-time jobs (an important consideration today in designing and evaluating teaching and learning strategies and technologies).

An important part of the educative process is answering student questions during the lecture. This allows common misconceptions and difficulties to be dealt with as they arise. It is important that students who miss a lecture have an opportunity to see these ‘asides’. Furthermore, online systems that foster cooperation, collaboration, social, and active learning are believed to provide opportunities for deep learning (Caladine 2005).

7.4 Taxonomy of Learning Technologies

A taxonomy of learning technologies has been developed by Caladine (2006a); this categorises learning technologies as either ‘representational’ or ‘collaborative’ (Figure 7.1). Technologies suited to one-way communication and presenting materials are referred to as ‘representational’ and technologies for two-way communications are referred to as ‘collaborative’. The latter category has sub-categories of ‘dialogic’ and ‘productive’. ‘Dialogic’ learning technologies only support the dialogue while ‘productive’ learning technologies support two-way communication and the simultaneous creation of materials.

Please see print copy for figure 7.1

Figure 7.1 Taxonomy of Learning Technologies (Caladine 2006a)

According to Caladine’s taxonomy, RTC technologies can be categorised in different ways. For instance, videoconferencing can be considered as collaborative, dialogic and synchronous when it is used to facilitate a conversation between remote parties. Web Conference Applications (WCAs) can also be seen as collaborative, dialogic and synchronous. WCAs are also productive when a product is created during the learning event. Similarly the Access Grid can be classified as collaborative, productive and synchronous when it is used as the host for collaboratively produced materials. Video Chat, a computer-based video communications tool, is collaborative and dialogic as it supports basic communication. Due to additional functionality, Enhanced Video Chat has the potential to be collaborative and productive. These technologies are described in greater detail later in this chapter.

RTC technologies are, by definition, collaborative and synchronous. That is, they facilitate two-way communications and interactions. For instance, the telephone is a two-way communication technology. Based on Caladine's taxonomy, it is classified as collaborative, dialogic and synchronous. It can be asynchronous when leaving a message. Other RTC technologies, for example the Access Grid, can also be used asynchronously when recorded for use after the session.

RTC technologies such as the Access Grid, videoconferencing and some Web Conference Applications are expensive and consequently they need to be implemented at the institutional level. They are usually installed by the department or institution. Institutional implementations may be accompanied by an imperative for staff to use them in teaching and learning. Other RTC technologies, such as Video Chat, are low-priced and not always implemented at the institutional level but are more accessible to individuals.

7.5 Real Time Communication Technologies

There was a wide variety of functionality in the Real Time Communication (RTC) technologies that were on offer and they varied widely in the number of participants who could access them at the one time. To facilitate their optimal implementation in teaching and learning, an appropriate means of comparison is required.

7.5.1 Videoconferencing

Videoconference technology gained prominence in the market in the 1980s. It took advantage of the digital telecommunication networks such as ISDN (Integrated Services Digital Network). Nowadays, videoconferencing generally uses the internet as the connecting network.
Videoconference technology allows two-way communication between geographically separated people. Point-to-point videoconferences (Figure 7.2) connect two venues and at each endpoint there can be one or more people. Multipoint videoconferences (Figure 7.3) connect more than two venues via a bridging technology (for example, a Multi Conference Unit or MCU). In this way, people can communicate with others in more than two locations (Caladine 1999).

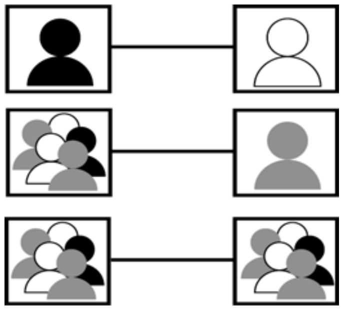


Figure 7.2 Point-to-Point Videoconference Configurations

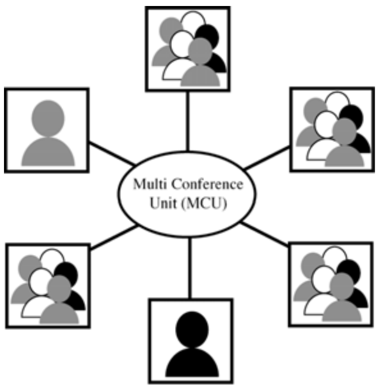


Figure 7.3 Multipoint Videoconference Configurations

7.5.2 Video Chat

Initially, Instant Messaging (IM) applications were restricted to text interchanges. They were normally free of charge as were the voice chat applications that followed. Video was a natural development following voice. For the purpose of this thesis, Video Chat is defined as an application of computer technology that permits two-way audio and video communication. Thus, Video Chat can be thought of as videoconferencing on a computer. Applications such as Apple's iChat AV show that the potential direction of Video Chat is towards a multipoint video communications tool with integrated file exchange and sharing, referred to here as 'Enhanced Video Chat'.

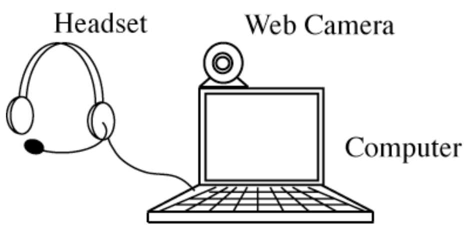


Figure 7.4 Video Chat

Video Chat is quite low-priced and straightforward to set up, as all that is needed is a computer, a web camera, a headset and an internet connection of sufficient bandwidth (Figure 7.4). This is the same hardware as that required for a personal interface to the Access Grid or PIG (Chapter 8). Most broadband connections are adequate for the use of Video Chat, which has been generally based on the use of web cameras. For this reason, there have been substantial limitations to their effective use, as most web cameras are not equipped with pan, tilt or zoom controls (Caladine 2008).

7.5.3 Web Conference Applications

Web Conference Applications (WCAs) are defined here as suites of web-based applications that permit sharing of applications, a computer-hosted whiteboard (or eWhiteboard), videoconferencing and other collaborative tools. As WCAs are synchronous, students can take advantage of them to discuss, question and interact. In this way, the technology can assist in achieving the learning objectives. Moreover, if the conference is recorded, the files can be used for other purposes such as revising the subject.

Several Web Conference Applications (WCAs) have been developed since Microsoft launched the first WCA, NetMeeting, in the 1990s. WCAs are used in research, education and training at the tertiary level. They are normally used for two-way communication in real time with shared applications or presentations (Caladine & Aminifar 2007). Examples include: Elluminate, Centra, and Acrobat Connect (previously Macromedia Breeze).

7.5.4 The Access Grid

The Access Grid is a computer-based application for two-way video and audio communication. It is open source software and uses a communication metaphor of virtual rooms. In this way, physical Access Grid rooms can connect to a 'virtual room' on an Access Grid server. The physical rooms are referred to as room-based nodes on the Access Grid and generally contain multiple data projectors and cameras that are equipped with pan, tilt and zoom functions. However, the Access Grid software can be installed on a computer with a web camera and headset. Such installations are referred to as PIGs or personal interfaces to the Access Grid. Full descriptions of room-based nodes and personal interfaces to the Access Grid are provided in Chapter 8.

Access Grid technology has been used for research as a collaboration and communication technology since its development in the mid 1990s (Caladine & Aminifar 2007). It takes advantage of the internet's multicast facility to send and receive multiple video and audio streams while keeping bandwidth to a minimum.

The Access Grid can be distinguished from videoconferencing and Video Chat by the multiple video streams that are sent and received from each endpoint or 'node', and by a number of additional software modules. Shared presentation, shared browser and true application sharing are examples of such modules. Some commercial products refer to the transfer of files between participants as application sharing. In fact, true application sharing allows participants to work on the same file synchronously. Personal interfaces to the Grid require similar technology to Video Chat. Room-based nodes are generally equipped with pan, tilt and zoom cameras that allow teachers and students to select what they see, thus assisting in the process of learning.

It is most likely that in positions and locations where travel is prohibitively expensive, the Access Grid has the potential to come of age quickly as an additional communication technology. Although the Access Grid has been used for some years in research collaboration, only in the last few years has its potential for teaching and learning (Chapter 8) become clear (Von Hoffman, Wiziecki & Arns 2007). The Access Grid learning experience is visually richer and more efficient than videoconferencing and Video Chat because of the multiple video streams sent and received. Another advantage of the Access Grid is that software modules allow participating lecturers and students to control the size of the received video windows and to control the cameras at other endpoints. The experience can be customised to suit participants on a level beyond that of videoconferencing and Video Chat. The Access Grid software also has modules that facilitate true sharing of files and applications and for this reason is categorised by the taxonomy mentioned earlier as both collaborative and productive.

7.6 Criteria for the Evaluation of Real Time Communication Technologies

The criteria by which the technologies were evaluated were those that were considered 'self-evident' in the centre that is responsible for evaluating technologies. The criteria are listed below and were based on perceived requirements for teaching and learning, given the demographics and computer resources available to students. The criteria are:

Mathematical Symbols

This is an essential criterion for mathematics-based courses such as science or engineering but especially for mathematics and statistics. Teachers must be able to provide problems and worked solutions.

Shared eWhiteboard

An electronic whiteboard that is shared between locations. Anything written on the eWhiteboard at one location immediately appears on all connected eWhiteboards. This is an important criterion for subjects with mathematical content as teachers of these subjects frequently use white or blackboards.

Application Sharing

This allows participants in different locations to work on a common file simultaneously (for example, spreadsheets, presentations and documents).

Two-way Communication

Two-way audio and video communication allows interaction between participants, for instance, teacher and students, and is considered to be the fundamental defining characteristic of the technologies compared (Daunt 1997; Kobayashi et al. 1997; Caladine 1999).

Electronic Capture

This is the ability to capture pen strokes from an eWhiteboard and save them for future use.

Cross-Platform

Technologies operate on a variety of operating systems such as Windows, Apple and Linux computers.

Text Chat

Technologies provide communication for support in the event of technical difficulties or for non-intrusive discussion.

Presentations (Live and Archived)

The ability to display presentations such as PowerPoint and to archive them for future use.

Participant Management

Participant management gives the presenter of the web conference session, control over who speaks when and allows them to answer or ignore questions from participants.

Breakout Room

This is the facility to host multiple subgroups.

Recordable

The interactions and displayed information can be recorded and replayed for later use.

Cost

- *Set-up cost*: Including equipment, room fit-out, video projector, camera(s), audio equipment, computer hardware and software.
- *License fee*: With the exception of the Access Grid, all of the applications have a license fee. The Access Grid software is open source and hence has no license fee.
- *Operational cost*: For instance, consumables, technical support (some suppliers provided technical support and in other cases it is left up to the institution), and bandwidth requirements which support different bandwidth connections.

7.6.1 Presentation of Mathematics Symbols

Students and teachers in mathematics-based courses must be able to represent mathematical and scientific symbols to communicate the discipline appropriately. In videoconferencing, mathematical symbols can be displayed when they are included in presentations using PowerPoint, LaTeX and other applications. They can also be presented using a document camera. Resolution was found to be an issue when a document camera was used with the Access Grid. The use of an eWhiteboard was favoured instead. These principles apply generally to any subject in which symbolic representation is required and would therefore be applicable to a broad range of disciplines.

7.7 Evaluation

A variety of RTC technologies is available for use in higher education. Their number was too great for a 'hands-on' evaluation of each one. For this project, a two-stage evaluation strategy was adopted. In the first stage, a list of suitable RTC technologies was constructed by considering the technology, as described in advertising and promotional materials, against the evaluation criteria. In the second stage, a trial of each short-listed RTC technology, which included WCAs such as Marratech, Elluminate Live, Wimba, Breeze, Centra (virtual classes), was conducted to check their ease of use, effectiveness and efficiency in teaching and learning. Several approaches to the comparison were necessary due to differing levels of access to each of the WCAs. For some, a demonstration by the supplier provided sufficient data to address the criteria. For others, 'hands-on' experience was obtained through free trials and access to licensed users of the application. Each RTC was evaluated against a list of criteria and the researcher recorded qualitative data on ease of use. At the conclusion of the evaluation, recommendations were made.

The criteria were selected on the basis of their relevance to the needs of teachers and learners, the institutional infrastructure and the literature. The criteria had to satisfy both departmental and institutional requirements (Table 7.1). Institutional criteria included cost, maintenance and technical support.

7.8 Comparing Real Time Communication Technologies

For the last two decades, videoconferencing has had an important function in distance education. Research shows (Mitchell 1993; Daunt 1997; Kobayashi et al. 1997; Caladine 1999) that videoconferencing is an effective interactive technology in teaching and learning and due to the similarities in the technologies, it appears reasonable to extend this generalisation to the Access Grid, Web Conference Applications, Video Chat and Enhanced Video Chat.

Technologies such as the Access Grid and Video Chat are becoming established in teaching and learning and due to the enhanced functionality of the Access Grid and the low prices of Video Chat, both technologies have the potential to play fundamental roles in teaching and learning. In this study, a comparison of the technologies on the criteria of function and cost assisted in assessing the future of these technologies.

The RTC technologies are all functionally similar, however they differ in type and level of functionality. For some criteria, there was no significant difference from one RTC to another and therefore criteria could not be used to differentiate between the potential success or otherwise of different RTC technologies in teaching and learning. By comparison, not all Web Conference Applications can fully support two-way audio and video as well as deliver images from a participant's computer. For example, subjected to the criterion 'two-way communication', the unsuccessful WCA was eliminated because of its difficulty in supporting two-way audio, not to mention two-way video. Videoconferencing, the Access Grid and Video Chat are characterised by two-way video and audio. With the exception of videoconferencing, all evaluated RTC technologies provided shared eWhiteboard, a separate text chat tool and true application sharing.

Table 7.1 Access Grid, Videoconferencing, Web Conference Applications (WCAs) and Selection Criteria

Criteria		**Access Grid**	**Videoconference**	**Marratech**	**Elluminate Live**	**Wimba**	**Breeze**	**Centra**	**Video Chat**	**Enhanced Video Chat**
Mathematical Symbols		Yes	Yes, via document camera or PowerPoint	Yes	Yes	Yes	Yes	Yes	No	Possible
Shared eWhiteboard		Yes	No	Yes	Yes	Yes	Yes	Yes	No	Possible
Application Sharing		Yes	No	Yes	Yes	Yes	Yes	Yes	No	No
Two-way Communications		Yes	Yes	Yes	Yes	One-way audio. Two-way audio available with permission	Yes	Yes	Yes	Yes
Electronic Capture		Yes	No	Yes	Yes	Yes	Yes	Yes	No	No
Cross-Platform		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Text Chat		Yes	No	Yes	Yes	Yes	Yes	Yes	No	No
Presentation (Live, Archived)		Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Participant Management		Not Applicable	No	No	Yes	Yes	Yes	Yes	No	No
Breakout Room		Yes	No	No	Yes	Yes	Yes	Yes	No	Possible
Cost	Set up/ Hardware	Room-based node – medium PIG – low	Endpoint – medium Bridge – high	Server – medium	Server – medium	Server – medium	Server – medium	Server – medium	Low	Low
	License/ Software	Open source – No license fee	Included – firmware	License – medium/high	License – medium/high Based on number of concurrent users	License – medium/high	License – medium/high	License – medium/high	Often free	Often free
	Operation (support)	Technician – medium	Technician – low	Technician – low (server support)	Technician – low (server support)	Technician – low (server support)	Technician – low (server support)	Technician – low (server support)	Low	Low
	Operation (Bandwidth)	Medium/ high	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

‘Operational support’ was one criterion which emerged as having impact at the institutional level. For example, the technical support required for the Access Grid was found to be far higher than that for the other RTC technologies. For this reason, it is recommended that the use of the Access Grid in teaching and learning be restricted to instances where high levels of technical support are readily available. Operational support levels were low for all other RTC technologies.

The WCAs evaluated all featured the facility to record and archive sessions. Recording of the Access Grid can be achieved through an additional piece of open source software called AG-VCR. However, the resulting files are large in size and can only be replayed with the Access Grid software. There are several ways in which videoconferences can be recorded. Some hardware vendors provide (at extra cost) servers that record the audio, video and computer presentations. Individual institutions have developed other systems. For example, at the University of Wollongong videoconferences are recorded using an in-house streaming/podcasting system.

Some of the WCAs offered participant management, for example, controlling who speaks. This was not viewed as a positive feature of the WCA as it was seen as a mechanism for controlling who participates when, and was judged to engender a teacher-centred approach. Perhaps participation control will provide a necessary tool for classes where student numbers are very high.

The equipment of the RTC technologies ranged from the simple to the complex, and consequently the costs ranged from low to high. However, the initial cost of each RTC was only one part of the cost criterion. Other elements of the RTC technologies that involve costs are software, personnel to support the technology and the costs of the network traffic. From an institutional perspective, cost is an important criterion.

License or software costs were medium to high for WCAs. As the Access Grid is an open source application, no license fee was required. For videoconferencing, the software is included in the hardware (firmware), so it is impossible to differentiate between hardware and software costs. With the introduction of any new technology into teaching and learning, there is a concomitant staff development cost. The greater the difficulty in using the technology, the higher the staff development cost. While staff development costs were not evaluated for each RTC, it is assumed that they will be approximately equal for all WCAs and videoconferencing. For the Access Grid, in cases where technical support is limited and the teacher undertakes some of the operation, the staff development costs will increase.

Recent versions of videoconferencing technology have included enhancements in the reliability, consistency and quality of both picture and sound. Conceivably the change that has had the greatest impact on the way in which videoconferencing is used is the change from ISDN to the internet as the network of transmission. The internet has decreased the necessity for designated videoconference studios that contain costly interfaces to ISDN.

Multipoint videoconferencing has medium to high set up costs due to the need for a device (bridge or Multiple Conference Unit) to support multipoint videoconference endpoints. Given that videoconference endpoint and bridging technology is expensive, it is logical to expect that its use will remain in specialist and professional areas such as high definition uses for medical imaging, microscopy and motion analysis, and high level board-meeting-style, immersive videoconferences. In the last decade, students have become used to Video Chat technology and as there are great cost savings to be had, it is reasonable to predict that the use of Video Chat in online and distance learning will develop and ultimately replace the videoconference. At the same time, since Enhanced Video Chat has the functionality of Web Conference Applications, without the expensive cost, it is rational to propose that Enhanced Video Chat will replace these RTC technologies.

It has been suggested (Caladine & Aminifar 2007) that cost alone is a sufficient driver to see institutions replace expensive videoconference endpoint equipment with the cheaper Video Chat. In addition, the enhancements of file sharing, and using Video Chat in conjunction with shared applications will facilitate its development into a collaborative, productive learning technology. This will permit students, wherever they are situated, to undertake a range of collaborative tasks such as building learning resources, compiling reports, debating issues, brainstorming ideas, and so on.

While the Access Grid requires no bridging technology or Multiple Conference Unit (MCU), set up costs are still medium due to the extra technology required. For example, the Access Grid requires echo cancellation equipment, multiple projectors and cameras. WCAs have medium set up costs for hardware and software if the decision is made to host locally. Most WCAs are available with either of two cost structures for their licensing. In one, the meetings or classes are hosted by the supplier and in the other the institution can purchase and install a WCA server and hence host its own web conferences. The second option is more expensive in the establishment phase but there are ongoing cost reductions in the bandwidth required for communications due to the local nature of the server and participants.

All RTC technologies are subject to costs when they use an Internet Service Provider (ISP) and logically the greater the bandwidth required, the greater the cost. Many institutions have minimised this cost through establishing their own network. Technical support levels for the RTC technologies vary. The experience at the University of Wollongong has indicated that the technical support costs for the Access Grid (Chapter 8) were high in comparison to the medium costs for technical support of the other RTC technologies.

There was a funding opportunity for the School of Mathematics and Applied Statistics at the University of Wollongong to take part in an inter-institutional collaboration in mathematics teaching and research through the use of the Access Grid (Chapter 8). The application for funding was successful and a room-based node on the Access Grid was installed in the School of Mathematics and Applied Statistics. A shared culture of use was seen as important for uptake of the Access Grid by the participating institutions. One of the reasons that the funding body chose the Access Grid was that it enabled participants to feel that they are in the same room because of the many concurrent communication channels. Other features of the Access Grid are:

- It uses multicast internet protocol, and no bridging or MCU technology is required.
- The software allows end-users to see images of all participants all the time and to select the size (small, medium or large) of each image.
- Two-way audio and video are provided.

- Any participant can control the computer images.
- True application sharing – such as spreadsheets, movie viewers, eWhiteboard and computer desktop sharing – is supported.

7.9 Conclusion

Real Time Communication (RTC) technologies assist students' learning as they are designed to be used synchronously, and can be recorded and applied asynchronously by students who did not attend the class, or for revision. Students can take advantage of synchronous technologies to dialogue, discuss and interact with their lecturers as opposed to interactions with materials.

It is reasonable to suppose that in the near future students will expect video and other examples of media-richness in their online learning experience. Over the past six to eight years, Learning Management Systems (LMSs) have played a significant role in learning and have been text-rich in both content and interactions (Caladine 2008). That is, their communications have usually been restricted to text. The LMS email system, chat sessions and forums have all been text-based. Since Video Chat is fast replacing text as the preferred and ideal medium for Instant Messaging, it is anticipated that Video Chat will be integrated with Learning Management Systems in the future. This integration will provide templates for use and promote secondary applications that will raise simple video communication and interaction to rich learning events. For example, a group of students engaged in a debate could be comprised of students in different locations with the discussion held in a virtual room on the LMS. A brainstorming session could be held between geographically dispersed students. A shared eWhiteboard, hosted within the LMS, can also be combined with Video Chat. Furthermore, it is possible to envisage the integration of the Access Grid with the LMS, which might allow the flexibility of having a small group at a regional centre and a larger group at a room-based node on campus interact as well with individuals at home on a Personal Interface.

Video chat has the potential for effective communication between at most two participants at each endpoint because web camera technology generally does not have pan, tilt or zoom. A class of many students, each with their own Video Chat, would be difficult, if not impossible, to manage. It is suggested, therefore, that Video Chat is suited to teaching and learning activities, such as consultation and postgraduate or honours supervision, which have small numbers of participants.

Adopting Access Grid technology has high initial costs. At the time of writing, two versions of the software are in use. Based on the difference in user-friendliness between these two versions, it is hoped that in three to five years time, the Access Grid software will develop to a level where significantly less operational support is required. In addition, if the current rate of development of compression algorithms continues, within three to five years the improvements will provide more efficient use of bandwidth. The general trend towards higher bandwidth connections is expected to continue. The combination of these changes will lead to a decrease in the bandwidth required by the Access Grid and hence lower costs.

In terms of technical functionality, the Access Grid can be pedagogically superior to videoconferencing and Web Conference Applications as it provides multiple video and audio of all participants as well as shared desktop, shared applications and shared whiteboard. As the Access Grid uses multicast, no local, expensive bridging technology is required. This makes the Access Grid more cost effective, in terms of the technological infrastructure required than for videoconference.

The Access Grid facilitates functions such as eWhiteboard and shared presentations that are not available as part of the videoconference hardware. As the Access Grid, Web Conference Applications and videoconferencing are functionally different; it is not recommended that all three should be used for teaching and learning at any one university. This conclusion is based on the extra costs that would be incurred, increased support required, and the extra time for students and teachers to become familiar with the different technologies.

While it is difficult to obtain exact figures, it appears that most Australian universities use videoconferencing in teaching and learning in some subject areas. More than fifty per cent of Australian universities have a room-based node on the Access Grid which is used more for research and meetings than for teaching and learning (Caladine, R. 2007, pers. comm., 22 May). A list of global Access Grid nodes, including some in Australia, is available at http://www.accessgrid.org/nodes.

An alternative to the Access Grid, under trial at the time of writing at the University of Wollongong, involves the combination of videoconferencing and Virtual Network Computing (VNC). By using VNC software, a computer can be connected to any other computer that runs the VNC software and is connected to internet. Different versions of VNC software are free or low-priced. VNC software is also cross-platform as it can be used on Windows, Apple, Unix and Linux operating systems. The videoconference carries pictures and sounds of the participants and also carries high quality images of computer presentations.

Virtual Network Computing (VNC) facilitates the two-way sharing of eWhiteboards and other computer applications. In this way high quality images are combined with shared computer screens. The benefit of the combination of videoconferencing and VNC over the Access Grid is the reduction of the required level of technical support. The disadvantage when compared to the Access Grid is that only one video stream is sent and received by each participating endpoint.

At the University of Wollongong, this research has led to the decision that Web Conference Applications will not be used in teaching and learning for the next three to five years. Instead videoconferencing will be used for at least that period of time. During this time further evaluation will determine if the Access Grid can replace videoconferencing for teaching and learning. Within the same time frame, it is also proposed to combine videoconferencing with technologies that permit the sharing of eWhiteboards and applications. These future approaches will be subject to ongoing evaluation, which will ultimately lead to recommendations for the institutional adoption of one or more specific technologies.

In the next chapter, one of the Real Time Communication technologies, the Access Grid, is described in greater detail. A trial of the Access Grid in teaching and learning mathematics and statistics subjects will be presented and evaluated.

Chapter 8

The Access Grid in Teaching and Learning

8.1 Introduction

In the past, distance education was normally characterised by independent learning and small amounts of dialogue between teacher and students. In the 1970s, the theory of transactional distance was established by Moore (Moore & Kearsley 1996). Transactional distance is measured by the degree of structure and the amount of dialogue in distance education subjects. Moore argued that communications between teachers and students in distance education ‘must be facilitated by print, electronic, mechanical or other devices’ (Moore 1972, p. 76). Real Time Communication (RTC) technologies have been used to facilitate audio and video communications between teachers and students (Chapter 7). The Access Grid is an RTC technology. This chapter reports on the third case study, which was a project that involved the use of the Access Grid to link teaching sites. Each site was equipped with cameras, projectors, an eWhiteboard and computers on which the Access Grid software was installed. This was used in the teaching and learning of mathematics and statistics subjects between several universities across Australia. The technology and arrangements of the facilities are detailed and a comparison of face-to-face and ‘Access Grid’ teaching is provided. Data for the comparison were gathered from interviews and questionnaires.

In recent years, there has been a movement from text-rich content to media-rich content on the web. Many students are used to media-rich online experiences and there is an expectation that Learning Management Systems (LMSs) of the future will have increased levels of media-rich content. There is also an expectation that media-rich Real Time Communication (RTC) technologies will be integrated with them. If these expectations are realised, a range of new online learning activities will be possible. As these activities are in the same area as online student records, connections between them will be facilitated.

An Access Grid node has been installed at the University of Wollongong (UOW) with assistance from the International Centre of Excellence for Education in Mathematics (ICE-EM). ICE-EM is a part of the Australian Mathematical Science Institute (AMSI).

> The International Centre of Excellence for Education in Mathematics (ICE-EM) has been established by the Australian Mathematical Sciences Institute (AMSI) to strengthen education in mathematics and its contemporary applications (http://www.ice-em.org.au/about.html).

The ICE-EM initiative was to establish a network of universities that were members of the Australian Mathematical Sciences Institute (AMSI) (Porter et al. 2007). The aim of the network was to use the Access Grid to enhance teaching and learning in mathematical sciences across universities in Australia. The Access Grid allowed members of AMSI to present lectures, seminars and also provided a facility for research collaboration between peers at national and international sites.

8.2 The Problem

Honours and postgraduate mathematics students who study at the University of Wollongong, like most students all around the world, would like the option of studying subjects which are not currently on offer. Generally, the number of students who want to study these subjects is small and class sizes of only a few students are not sufficient to run the subjects. The ICE-EM initiative indicated that there were similar, small numbers of students at other Australian universities. To overcome this problem, technology was seen as a way to deliver virtual subjects throughout the nation or indeed to the world. Subjects could be shared between students in different geographic locations and they could interact with lecturers who are experts and professionals in the subject area but who are located elsewhere. The ICE-EM offered funding to establish Access Grid rooms at Australian universities (http://www.ice-em.org.au/AGR/index.html).

In 2006, the Access Grid rooms were installed and used for teaching and learning mathematics and statistics at a small number of Australian universities.

8.3 The Proposed Solution

The ICE-EM solution was to develop a network in which teaching was shared between universities across Australia. The Access Grid was the technology selected by them to do this.

8.3.1 Access to a Variety of Subjects

Technology provides essential tools for delivery of online subjects for universities and other institutions. For those technologies which facilitate two-way communications, academic staff could teach students from their own universities as well as students at different locations. In this way, small numbers of students who do not have an opportunity to access subjects locally could share with other students. With cross-university teaching and learning, numbers of students would increase. One of the benefits of teaching between universities is the potential for reciprocity. For instance, one subject taught at University A, is shared with Universities B and C and another two subjects are taught from Universities B and C to all three universities. Therefore, an academic at each university teaches one subject, while three subjects have been offered to all students. In this way, efficiencies can be obtained as the teaching loads can be decreased while offering a wider range of subjects to students.

The reciprocity was limited to three universities in the Spring Session of 2006, with three subjects on offer. In the Autumn Session of 2007, five subjects were on offer among the same three universities. The ICE-EM website indicated (http://www.ice-em.org.au/AGR/subjects_and_courses.html) that the number of universities participating in the initiative would increase in the 2007 Spring Session to eight universities offering eleven subjects (Table 8.1). At the national level, the mathematics and statistics subjects were available for reciprocal participation via the Access Grid nodes for members of the Australian Mathematical Sciences Institute (AMSI).

Another benefit of the cross-university teaching and learning approach is that students could review subjects at other universities while choosing their own postgraduate studies program. The Access Grid also provided opportunities for academics at different universities to collaborate on research. Overall, the goals of the ICE-EM Access Grid room project were to:

- enhance effectiveness and efficiency in honours subjects,
- increase the diversity of subjects taught across universities,
- expand the nexus between research and education and
- improve research among academic staff through providing opportunities for seminars and collaboration.

The Access Grid is a two-way communication technology that has been used for teaching and learning of subjects at university level over the internet. Local and remote students from different campuses and universities can interact and collaborate in real-time. Accordingly, there is no need for students to wait for the lecture to be recorded and posted to them as is the case with the technologies of asynchronous streaming and podcasting. In these technologies learning materials are recorded and delivered in a one-way manner from the academic staff to the students.

Table 8.1 Subjects on Offer during 2006 and 2007 via Access Grid in Australian Universities

Subject	Spring Session 2006 (Semester 2)		Autumn Session 2007* (Semester 1)		Spring Session 2007* (Semester 2)
	Host	**Shared with**	**Host**	**Shared with**	**Host**
Financial Time Series	South Australia	UOW			
Nonlinear Ordinary Differential Equations	UOW**	La Trobe			
Group Actions and Geometry	La Trobe	UOW			
Topology and Dynamics			La Trobe		
Advanced Optimisation			South Australia		
Optimal Control			South Australia		
Modern Inference			UOW		
Advanced Data Analysis			UOW	RMIT and South Australia	
Multivariate Analysis					Macquarie
Waves in Fluids					Monash
Convex Analysis and Control					RMIT
Game Theory and Applications					RMIT
Topological Groups					Newcastle
Financial Time Series					South Australia
Introduction to Analytic Number Theory					South Australia
Chaos					Southern Queensland
Statistics for Climate Research					Southern Queensland
Modules and Group Representation Theory					Sydney
Cryptography, Computer and Network Security					Victoria
Survey Design and Analysis					UOW

Some subjects on offer did not necessarily run.
***** http://www.ice-em.org.au/AGR/subjects_and_courses.html
****** The University of Wollongong

8.3.2 The Access Grid Defined

As described in Chapter 7, the Access Grid is a computer-based technology that contains high-end audio and video technology which enables group-to-group collaboration in a visualisation environment. The Access Grid software facilitates two-way audio and video communications (http://www.accessgrid.org/; Caladine 2008). The Access Grid is a live collaboration technology as it uses two-way synchronous interaction. The two levels of installation of the Access Grid were referred to as personal interfaces to the Access Grid (PIG) and room-based nodes. One of the advantages of the Access Grid is that the software is open source which means it is available at no cost and can be downloaded from the Access Grid website.

PIG is a low level installation which requires a computer (Windows, Apple or Linux), a web camera, a headset, and an echo cancellation device (Figure 8.1). Often a headset which includes a microphone will provide sufficient separation of incoming and outgoing audio, hence cancelling echo. All nodes on the Access Grid require high bandwidth connections to the internet. Most Australian universities have these in sufficient supply. PIG facilitates individual needs and it is appropriate for small groups of participants, for instance researchers, developers or postgraduate students.

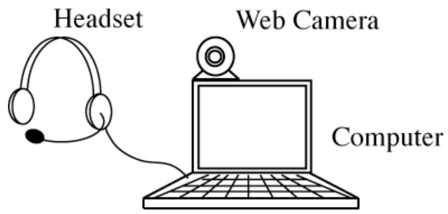


Figure 8.1 Personal Interfaces to the Access Grid

Room-based nodes on the Access Grid typically contain a wall of projected video images, as shown in Figure 8.2. They facilitate larger group-to-group communications and collaboration. Furthermore, they create a visualisation environment in which audiovisual hardware provides images of all participants which can be seen along with images of documents, computer screens, eWhiteboards and other applications (Figure 8.3).

Figure 8.2 Multiple Video Streams of the Access Grid, Using Document Camera for Local and Distant Students

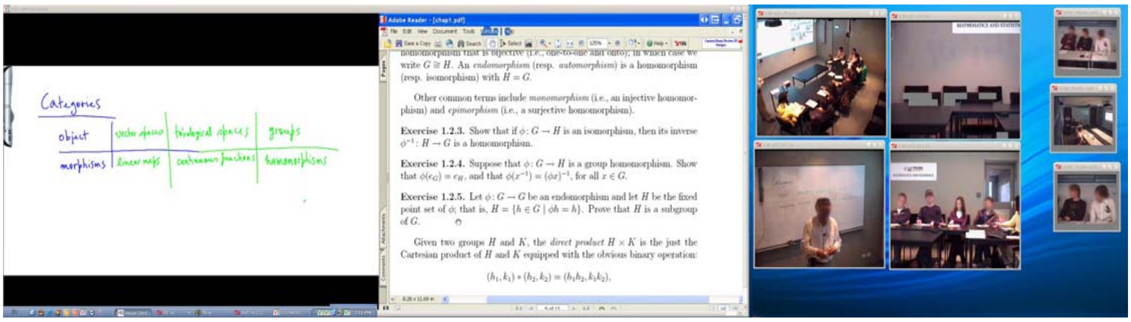


Figure 8.3 Mimio, Shared Applications, Local and Distant Lecturer and Students

The Access Grid provided opportunities for members of AMSI to share mathematics and statistics subjects, seminars, and collaborative research throughout Australia in real-time. As mentioned earlier, it has been used for teaching and learning mathematics subjects between universities across Australia.

8.4 Funding Sources

The School of Mathematics and Applied Statistics at the University of Wollongong received funding of $77,000 AUD from the International Centre of Excellence for Education in Mathematics (ICE-EM). This funding was allocated to purchase the equipment, both hardware and software, for the Access Grid room. Each participating university had to provide in-kind support for a number of aspects of the project as well as purchase non-equipment items. The Head of the School of Mathematics and Applied Statistics provided a commitment to the project and made a room available. He also provided the school funds for the purchase of curtains, appropriate lighting and for the painting of the room. The Centre for Educational Development and Interactive

Resources (CEDIR), a central support unit at the University of Wollongong, also provided in-kind support. CEDIR staff managed the procurement and installation of equipment as well as commissioning the facility. CEDIR staff also provided training for academic staff from the school as well as technical maintenance and support.

Since the technology is complex, at first training was limited to operation with pedagogical training to follow. Pedagogical training was delivered little by little, rather than confronting academic staff with the need to fundamentally change the way they taught. Academic staff and students at different universities were interviewed and some were surveyed regarding their experiences in teaching and learning via the Access Grid. The results of interviews and questionnaires are discussed in Sections 8.7 and 8.8.

8.5 The Access Grid Technology Installed at the University of Wollongong

The technology used in room-based nodes on the Access Grid can be categorised as video capture, video display, audio capture, audio replay and the sharing of computer images.

The video capture equipment consisted of three cameras to capture images of participants and the room, a document camera and a video capture card as the interface between the analogue outputs of the video cameras and the digital requirements of the computer. The video display equipment consisted of three projectors connected to the display cards in the computer. The video equipment displayed images of the local and distant participants and the materials used. As some participants were local and others at distant universities, an interactive electronic whiteboard device (Mimio) was used to display material that traditionally would have been written on the blackboard or whiteboard.

Mimio is a technological tool that uses a receiver attached to a standard whiteboard to capture, record, convert and present every step that is written or drawn on a whiteboard to the local and distant participants. The pens or stylus are enclosed in sleeves that transmit a signal to the receiver, a technology which is similar to the eBeam technology described in Chapter 4. It allowed students to share the eWhiteboard and to access the files created on it for later use.

Audio capture equipment included four microphones, an echo cancellation device and an audio card. These were used to capture audio from participants in the Access Grid room. Audio replay was used to make the speech of participants at other universities audible; loudspeakers were connected to the amplifier built into the echo cancellation device.

The computer formed the central technological component of the Access Grid room as it hosted the Access Grid software which consisted of the Venue Client, the Robust Audio Tool (RAT) and the Video Conference Tool (VIC) (Figures 8.4-8.6).

Please see print copy for figure 8.4

Figure 8.4 The Venue Client

Please see print copy for figure 8.5

Figure 8.5 The Robust Audio Tool (RAT)

Figure 8.6 The Video Conference Tool (VIC)

Due to different versions of the Access Grid software being used at different participating universities in 2006, collaborative elements of the Access Grid, such as shared browser and shared presentation, did not work properly. Therefore, Virtual Network Computing (VNC), which is a free piece of software, was used to overcome this problem and connect desktops. Virtual Network Computing is often used for the remote maintenance and administration of computers. It provides remote access and control of computers and displays the remote computer desktop. VNC was used in conjunction with the Access Grid software to share desktops, presentations, and to interact with others across the network.

At the time of writing the most recent version of the Access Grid was 3.0.2 (Version 3.1 is in beta release). The Access Grid software included the Access Grid Toolkit 3.0.2, Python 2.3, Python win32 extensions, wxPython 2.6 and Bonjour which were all available as free downloads at http://www.new.mcs.anl.gov/fl/research/accessgrid/software/releases/3.0.2/windows.html. Audio and video are transmitted via the internet using multicast where available. The conferencing tools in the Access Grid are the Robust Audio Tool (RAT) and Video Conferencing Tool (VIC).

Unicast and multicast are internet transmission protocols. Unicast facilitates communication by sending media and data in a single stream to each destination over a network. Multicast provides delivery of media and data simultaneously from a single stream to a group of nodes or destinations. Multicast is similar to sending a single email to a group of recipients. The Access Grid makes use of the internet's multicast protocol, to minimise bandwidth while sending a video stream to many receivers (Figure 8.7). Therefore, multicast needs to be enabled on the network for the Access Grid to operate as efficiently as possible. This reduces bandwidth costs and increases Access Grid's appropriateness for academic and research purposes. As some universities had multicast enabled on their networks and others did not, multi/unicast bridges were used to allow connections between them.

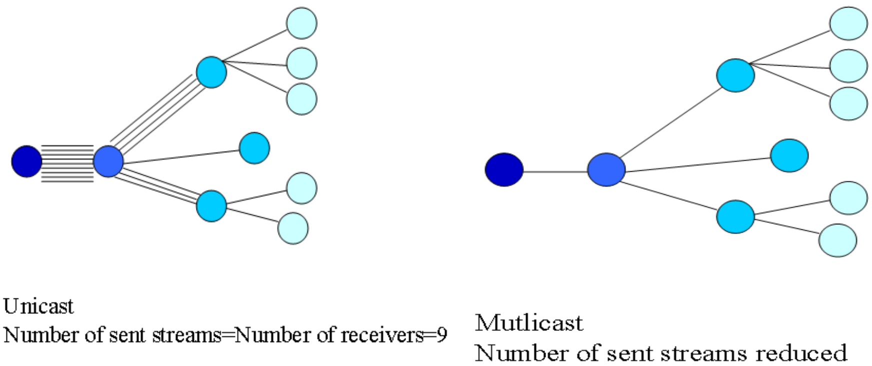


Figure 8.7 Unicast and Multicast

From other surveys, this was often considered problematic. Daw (2006) drew attention to a common problem:

> Not being on multicast, we occasionally forget to switch to the unicast bridge – easily forgotten! It would be good if the AG client could remember this when it connects and do so automatically, or at least prompt (p. 5).

The computer also ran the software for the eWhiteboard (Mimio), delivered images to the projectors, processed video from the cameras and processed audio from local and remote participants.

A detailed list of the hardware used in the University of Wollongong for the Access Grid room is provided in Table 8.2 and a schematic diagram of the equipment is shown in Figure 8.8.

Table 8.2 The Access Grid Equipment Details and Costs

Hardware/Equipment	Details	Use/Justification	$AUD
Two Windows Computers (rack mountable)	Stealth Audio	Central technological component of the Access Grid including: video capture card, multi-display card and audio card	7998
Two LCD screens	Dell Ultra Sharp 17"	Operator screens	1510
Three Cameras with remote control	Sony EVI-D100	Video capture from the room	3600
The document camera*	Elmo 5600XG	Video capture of documents, small items	4820
Interactive whiteboard	Mimio Xi plus wireless module	Pen capture from whiteboard	1705
Projector	Hitachi CP-SX5600	Display of high resolution images including application sharing	7270
Projector	NEC HT1100	Display of far end participants	5450
Projector	NEC LT245	Display of Lower resolution images e.g. shared whiteboard	3750
Three projector mounts		Ceiling installation	900
Two projector screens	custom built 5m × 1.8m		2396
Echo cancellation device	ClearOne XAP400	Echo cancellation and audio mixing	7500
Two loudspeakers	Genelec 1029A	Far end audio	2950
Four tabletop microphones	Beyerdynamic MPC66	Audio capture	1400
Cables	-	-	2000
Two equipment racks	-	-	760
In-ceiling lighting	Low voltage gimbals mounted	To provide adequate lighting of local participants	1200
Total			**$55,209**

* The document camera was used in Spring Session 2006 as the Mimio was not ready to use.

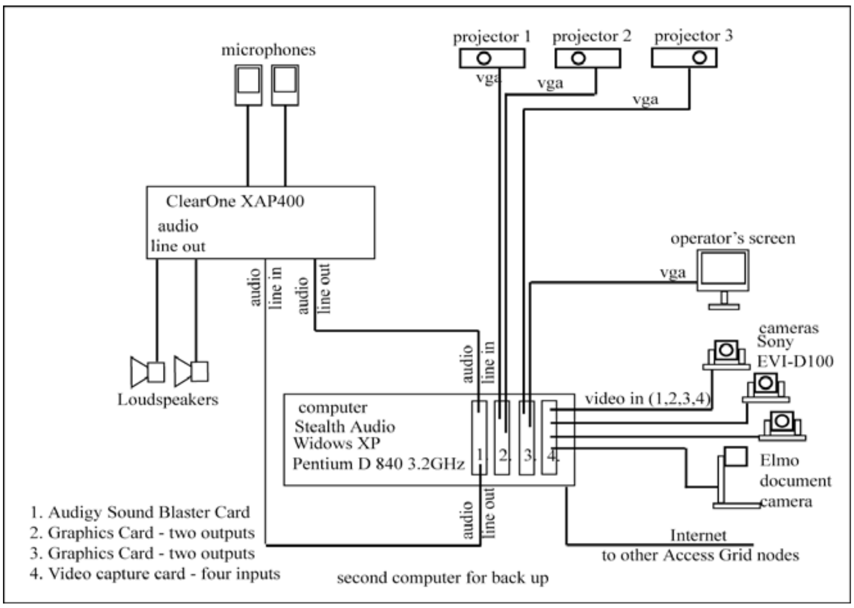


Figure 8.8 The Access Grid Equipment Schematic

Non-equipment items that were required for the Access Grid room were funded by the School of Mathematics and Applied Statistics. These included painting, some carpentry and curtains. The room was air-conditioned and the existing furniture, consisting of eight desks and sixteen chairs, was used. A diagram of the layout of the Access Grid room is shown in Figure 8.9. For the Access Grid to perform, a high bandwidth connection to the internet was required.

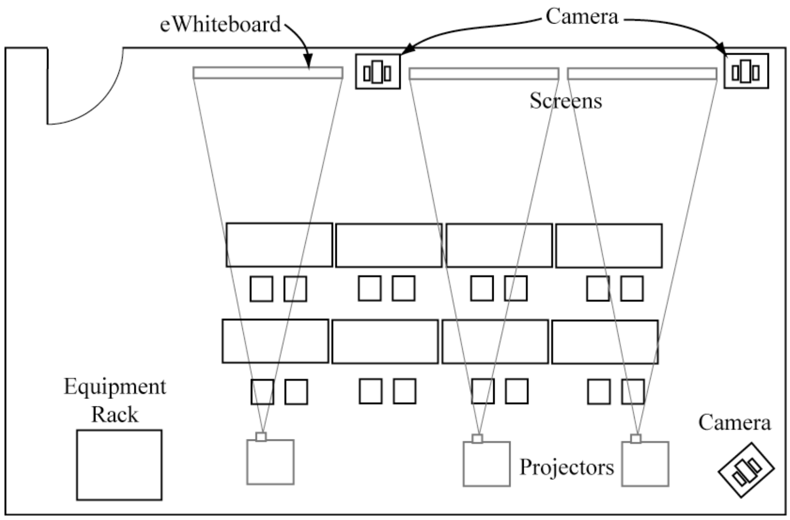


Figure 8.9 Layout of the Access Grid Room

The Access Grid room, which is in the School of Mathematics and Applied Statistics Building, was equipped with a 100Mbps network to the desktop, and the network architecture supported multicasting. Information Technologies Services (ITS) at the University of Wollongong enabled and maintained multicasting as well as the configuration of firewalls and other security measures. At the time of writing Information Technology Services (ITS) is a central unit of the University of Wollongong. ITS supports the university's information technology infrastructure, which incorporates the provision of computers, network and communication services for teaching, research and administration.

8.6 Teaching and Learning with the Access Grid

Technologies in teaching and learning often impose limitations. As teaching and learning using an Access Grid was considered to be different from face-to-face teaching, the literature was consulted to review the approaches taken by others. A format for teaching and learning making use of this technology was determined in conjunction with the lecturers. Some lecturers adopted the new format and others were more reluctant to change the way they taught. While a comparative study would be beneficial as a guide to future teaching using the Access Grid, an in-depth study is beyond the scope of this thesis.

8.6.1 Existing Approaches to Teaching and Learning with the Access Grid

There is a lot of literature on the technical aspects of videoconferencing and a smaller amount on the technical aspects of the Access Grid. However, there is a very limited amount of literature on the use of these technologies for teaching and learning. As the Access Grid and videoconferencing technologies are similar in function, the literature concerning videoconferencing in teaching and learning was drawn upon to guide teaching with the Access Grid. The educational videoconference literature agrees on the importance of interaction to the process of learning using this technology. Some lecturers used the guide while others did not change their approach.

> This is an interactive medium and a visual medium. I believe it works particularly well with relatively small groups of say, twenty or thirty and in situations where students at both sites can interact with their peers as well as with their teacher, tutor or trainer. It is an excellent technology for cognition building for tutorials, role plays, simulations, brainstorming, problem solving, case study work and so on (Mitchell 1993, p. 76).

Daunt (1997) highlighted the significance of interaction in videoconferences. She described 'teleteachers' as facilitators of videoconferences in learning as:

> Most teleteachers agree that interaction is an important element in their teaching - after all it is the only thing that distinguishes teleteaching from a video tape! Interactivity takes many forms; it is not just limited to audio and video, or just teacher-student interactions. It represents the connectivity students feel with the teacher, the local tutors and their peers (p. 109).

Laurillard (1993) illustrated videoconferences as a discursive medium. Laurillard suggested that 'As a way of transmitting a didactic lecture, a video would be cheaper and easier' (p. 167). Kobayashi et al. (1997) revealed that in their experience with videoconferences at university level:

> … the least effective forms of discourse were those which were monologues/explanations/lectures, where the sole purpose of communication was the transmission of information (p. 247).

Experience with videoconferences in learning seems to indicate that they are better suited to interaction rather than presentation. One-way presentations such as lectures are not generally appropriate for videoconferences and it is probably cheaper, as well as more educationally effective to use a one-way technology for these kinds of teaching and learning activities such as text, audio or video recordings (Caladine, R. 2007, pers. comm., 22 May).

8.6.2 Techniques for Teaching and Learning with the Access Grid

The intention was to teach from the University of Wollongong using the two-way audio and video features of the Access Grid, shared PDF documents and eWhiteboard. However, in Autumn Session 2006, due to problems with the eWhiteboard (Mimio), the document camera was used instead. After the problems were fixed, the Mimio was used in Spring Session 2006 and Autumn Session 2007, while it was replaced with a touch sensitive whiteboard in Spring Session 2007. Touch sensitive whiteboards are more robust but more expensive that the Mimio style of technology. However, a special stylus is not necessary for use, as pressure on the whiteboard, even from a finger, determines the location of the mouse or virtual pen.

The subjects taught using the Access Grid in 2006 and 2007 were listed earlier in this chapter in Table 8.1 and an evaluation of them is provided in the next sections.

Most of the evaluations in the literature were from the perspective of staff, presenters and their seminar audience, technical experts and those responsible for the Access Grid nodes. Problems in the use of the Access Grid were identified in survey of Access Grid users in the UK (Daw 2006), a survey on multicast and the Access Grid in Canada (Patrick 2005) and an AARNet survey on video over IP in the Australian academic and research sector (2006). Not surprisingly, early in the adoption of the technology, the surveys focus on technical issues such as the inability to use multicasting with some nodes dependent on unicast.

Daw (2006) reported that the responses for improvements of the Access Grid were for more reliability (35%), greater coverage of the Access Grid across organisations that do not currently have it (16%), better audio (12%), better video (7%), better data sharing, integration with other applications (4%), more interoperability with other technologies (4%), and the ability to easily contact other sites when there are problems (4%). Many of these issues had arisen, although reliability appeared to improve from the first to later implementations.

In this research, it has been possible to have both lecturers and their students recount their experiences based on perceptions in a subject taught using the Access Grid.

8.7 Student Evaluations

Students were interviewed and/or surveyed regarding their experiences in teaching and learning via the Access Grid (Appendix 14). These data allow an examination of:

- students' experiences of the Access Grid at the host university, that is the university where the lecturer was based,
- students' experiences of the Access Grid at the distant university, that is students not located at the university hosting the subject and
- comparison of a PIG and a room-based node on the Access Grid.

When ethics clearance was requested it was not assumed that the students' anonymity could necessarily be maintained, as the student group involved in the Access Grid trials was extremely small. In the Participant Information Sheet (Appendix 7), students were informed:

> However, in asking you to participate in these interviews, we recognise that anonymity cannot be guaranteed within the institution, as there are only small numbers of students and lecturers involved. The findings of the research will be published in a thesis and journal articles (Aminifar et al., Ethics Approval Number: HE06/268).

Even so, in this section pseudonyms are used. Gender remains the same. In addition, because some of the students were of non-English speaking background, responses were condensed and clarified when the respondent's English was confusing.

As the pool of students was very small, interviews were used as the first evaluation instrument. This allowed the follow-up and clarification of issues arising from the interview, ensuring the usability of the interview data. The researcher had English as a second language and, because it was necessary to ensure that the nuances of the language were detected, the student interviews were audio-taped and transcribed (Appendix 9). The interviews also provided the opportunity to trial questions for use in a survey format. As the interviews revealed there were special cases where students had experienced two forms of the technology, the room-base node on the Access Grid and the PIG, the interviews are the last of the student data discussed.

As the number of students attended for each class was small, just nine students completed the interview questions in a survey format. These include six students from the University of Wollongong, one student from La Trobe University, and two students from RMIT University. Six of the students took the subject at the host university and two took the subject from a distance. One of the students responding did one subject at a host university using a room-based node and a second one received from a PIG, in a host university, as a distance student. The remaining students took part with a room-base node on the Access Grid facility.

8.7.1 Surveys: Students at the Host University

Six students who completed a subject at their host university responded to the survey. Five of these students were from the same university. The analysis examined the experiences of students who found:

- traditional teaching is better,
- no difference between the Access Grid and traditional teaching and
- the Access Grid is better.

8.7.1.1 Traditional Teaching Is Better

Three students, Sunee, Ivan and Jamal who took the subject at the host university, considered that the traditional approach was better than the Access Grid. All three of these students were of non-English speaking background and their education up until this point had been done in countries outside of Australia. This should be noted, though a thorough examination of the relevance of this is beyond the scope of this thesis. For Sunee, traditional learning was the best as she was used to it. Ivan commented that he thought traditional learning better because even though the Access Grid meant that they were able to share the subject with other universities, they were not able to ‘share the knowledge’ with them. He also found the whiteboard ‘hard to use’. Jamal thought that ‘when you are facing the lecturer, you get more benefits’ because he found it easier to hear and understand the lecturer better.

When asked about whether or not they had sufficient background, Jamal said: ‘yes’, Sunee was ‘not sure’ and Ivan added that it was hard to follow because ‘I do not have enough background in mathematics and programming’.

They were mixed in their reactions as to whether or not they were comfortable with discussion: Sunee was comfortable and found it good to share discussions with remote students; Jamal did not engage in discussion but stated that he would have been able to do so; while Ivan was comfortable to discuss problems with the lecturer but not with other classmates. Ivan considered discussion about mathematics inappropriate because he felt that, unlike other subjects perhaps where discussion could be useful, mathematics was not a matter of opinion. He felt that ‘we should follow the lecturer’.

From a technical perspective, they could ‘mostly’ read what was on the screen, but this was qualified because they often found it difficult if the lecturer did not write ‘big size’, especially when writing subscript or superscript.

Sunee detected that there were likely to be differences at the distant university but did not elaborate. Ivan indicated sometimes there were technical problems. This was not a problem for the other two students. Synchronisation of the video and audio was said to be ‘fine’.

Sunee, Ivan indicated that they were ‘comfortable’ with the way they could listen and hear other students but Ivan noted that the lecturer needed to speak ‘clearly and slowly’.

Ivan conveyed his difficulty with understanding the language a number of times in the survey. For Sunee, interacting with other participants was ‘easy’ but Ivan found this type of interaction lacking. He said that he did not know how good the audio was at the other site since he had never seen the participants discuss a maths topic. He thought it would be easier if the lecturer gave them time to discuss.

When asked about what impressed them most about the Access Grid, Sunee focused on interaction ‘Discussions between far away students and us’ and least impressive, the ‘small screen’, (the size of the screen is manipulated by the operator). Ivan found the most impressive aspect was the useful resources, ‘The written whiteboard can be kept which is convenient when I cannot follow …’. For him the least impressive part of the Access Grid experience was the time they had to copy what the lecturer wrote down. He also was annoyed by the fact that the whiteboard tended to draw lines when there was a gap in the notes.

They considered the layout of the room ‘appropriate’.

For the students the best thing about the Access Grid was, for Sunee, the capacity for ‘sharing remote resources’. Jamal agreed, ‘It can make the study available to all’.

In response to the question ‘anything else’ they would like to mention, Sunee found it, ‘quite a new experience and enjoyed it’. Ivan offered a comment in relation to staff training.

> The lecturer, who will use this room, should try to use this room before the class begins. Otherwise, they will waste time to learn how to use it.

8.7.1.2 No Difference between the Access Grid and Traditional Teaching

One student, Amitabh, who completed the subject at the host university, believed that the experience of the Access Grid was equivalent to that of traditional teaching,

> I believe it the same, and the lecturer has an electronic whiteboard which is practically the same as using a normal whiteboard.

He shared the subject with students from two other universities. He considered that he

> had enough statistics and mathematics background to do the course. The discussion was interesting; it was hard in some aspects as I only had a basic understanding in statistics.

By the end of the subject, he felt that it ‘made sense’. He did not find any problems in reading from the whiteboard, but he was annoyed by the lines which would keep appearing when there was a gap in the notes. Apart from that, he felt that the software and the lecture notes had no problems, ‘… everything else worked fine’.

Amitabh, a student at the host university did not detect any differences between the experiences of the host university and the distant university except that ‘the lecturer is in the same room as the student at the [host] institution and at the [distant] institution the lecturer was displayed on a screen’.

Amitabh did experience problems but these were academic problems, in particular with ‘non-continuous response variables’. As a consequence, he had contacted with his lecturer. In terms of assessment Amitabh felt that his grades ‘were the same’ as he expected.

The technical issues appeared minimal for Amitabh,

> There was one occasion when there was an echo within the room, but was easily fixed by the lecturer. Since I was in the Access Grid all the material presented to me was easily understood and something there was no connection between the [host] campus and the other campus. The notes were posted on the net so the students who missed class could easily catch up.

He did not experience problems with using the software packages required. Asked about how well the audio and video were synchronised, Amitabh changed the subject and spoke about the value of the Access Grid instead, noting its benefits to students because it enabled them to take subjects to which they would otherwise not have access. He did indicate, however, that staff training still needs ‘a lot of work to be done … on how to use the new system’.

Asked about his interaction with the lecturer and students from the other universities Amitabh indicated that he

> … found it alright. I was already experienced with the Access Grid with an accounting subject that I did in first year.

It is likely that the student has confused the use of videoconferencing with the Access Grid as this was not in use at his university for subjects other than mathematics. He did not note any difficulties in communication but indicated he had really ‘… only interacted with student at the [host] campus’ because ‘the class didn’t really interact with the student from the other campuses’.

When asked about what impressed him most it was, ‘the new technology’. Amitabh offered no strategies as to how to improve the Access Grid experience or to improve his understanding and learning of mathematics. He considered that there was no problem in the layout of the room because of the small number of students in the class, but thought that it might have been a problem if there had been more students at one university of the other.

Amitabh was least impressed with ‘the training of the staff to use the Access Grid technology’. Like staff and other students, he indicated that the main benefit of the Access Grid was its ability to link up various universities thereby giving students access to a greater range of subjects.

8.7.1.3 The Access Grid Is Better

Two students, Quang and Robert, indicated that they thought the Access Grid experience was better than traditional teaching. They were from different universities and Quang, like some previously mentioned students, was from a non-English speaking background. Robert's subject was shared between three universities. Quang shared the subject with two students from other universities and there were ten students at the host university. Quang felt he had a reasonable background suitable for discussion with other students.

Robert felt he could remedy any missing background. If he ever needed to, he saw the lecturer on the host university, 'I would just go during consultation hours'.

Both these students considered the Access Grid better than traditional teaching.

> Robert: For this subject I believe that teaching via the Access Grid was better because there was a bit of computing in this subject and it was well presented during lectures. Another advantage was that all presented material was on the internet, which doesn't usually happen with other subjects.
>
> Quang: I think it is better to learn via the Access Grid than normal learning and teaching because in this room lecturers with the support of electronic instruments don't need to spend time on writing all content of the lectures notes on the board so they have more time to explain and answer the questions of learners. Using electronic materials for example pdf files on the screen gives the learners a better view of the lecture notes. Students in the class can communicate with others from different places and this makes the class more interesting.

Only Quang responded to the question 'Were you comfortable with the discussion?'. For Quang his comparison was with his home country, where he thought that teachers were less helpful and friendly than in Australia.

The academic preparation and the technical aspects of the Access Grid appeared satisfactory to these students. Robert felt that the lecturer was always 'well-prepared' and was able to use all the elements of the Access Grid technology (slides, eWhiteboard, software) 'very well'. Like other students, he noted the problems with the eWhiteboard and the lines, but he did not think it affected the lecturers 'that much'. He liked being able to demonstrate the use of a computer program during the lecture without having to go into a separate computer lab. He also felt that everything on the screen ‘was easy to read although sometimes [the lecturer] would need to clarify some symbols’.

Quang found learning via the Access Grid ‘very interesting’. He appreciated the eWhiteboard which ‘can give all the content written on it to be presented on the wall in the classroom and in another classroom in a different place’ but perhaps because English is his second language, he sometimes found that the loudspeakers ‘didn’t work very well and it was quite difficult for [him] to hear students from the other place speaking’. He thought that the projector worked well and that ‘everything appeared on the screen clearly’.

The students at the host university were unable to detect any differences for students at their university and those at the distant university. Robert commented that he did not really know how distant students found the lectures. Quang also said he did not know how he might have felt if he had been in the distant venue and thought there might be some problems.

For these students, the problems were more academic than technical. Robert found difficulties with assignment questions. However, he felt that these seemed to ‘tie in well’ and that there was ‘a good mix of computing and theory’. He also thought that his results were ‘about what [he] expected to get’. Quang was also satisfied with his marks on the ten assignments and three presentations which he had to do.

Both students had met with their lecturers to resolve matters and found the lecturer to be available and accessible. They could see him in his office or on the Access Grid if something was not clear or when they needed help.

From a technical perspective, neither student seemed unduly concerned about technical issues although Robert’s experience was more positive than Quang’s.

> Robert: The only problem that sometimes affected me was the eWhiteboard playing up (sometimes it would just write scribble). Honestly it didn't bother me if I couldn't see the other students on video … My lecturer usually had someone helping prepare the set-up before the lecture. He was always well prepared. He just put all the needed files on the internet. This was probably the easiest way of doing it.
>
> Quang: Yes, there were several times we had difficulties in listening to others from Wollongong and they couldn't hear us … we can lose five or ten minutes to wait for the lecturer to make sure the other place can hear and see our side.

Neither student had difficulty in sharing data files such as Excel or SPSS. Both considered the synchronisation of the audio and video to have 'worked well' or 'worked all right'.

Both students were comfortable interacting in discussion. Robert thought it was not important to actually see the distant students but, although he thought it was 'good', he observed that not a great deal of interaction between students at the different sites actually took place and commented: 'I didn't really try to interact'. Quang found the Access Grid 'very interesting' and even commented that he felt 'very comfortable with it'. He felt he had more time to ask questions. One problem, though, was that while '… it was easy to interact with other participants on my site', it was harder to hear students from the other site. He did comment, however, that 'I think the reason was at that time my English was not good enough (I had just come in Australia before doing this subject)'.

The least impressive attribute of the Access Grid technology was for Robert, 'the faults with the eWhiteboard technology' and for Quang who had difficulties understanding English, 'the loudspeaker didn't always work well'. Neither the room nor the layout was an issue for either student. Interestingly, Robert commented that the lecturer 'treated the camera like another student so it was not really any different to another "normal" lecture'.

Quang had been taught through videoconferencing, but he preferred learning via the Access Grid and he found the use of the Access Grid in teaching and learning 'useful and interesting'. He liked the eWhiteboard and found it 'very useful'. He also found it 'very interesting' to share the subject with students from other universities.

He did have a request for improvement:

> Although the eWhiteboard was very useful and interesting, the content which appeared on the wall was not completely the same as what the lecturer wrote. It was not very easy to become familiar with writing on this board.

An improvement suggested by Robert was an extension of the academic explanation, requesting more 'detailed computer demonstrations'. What Robert saw and most appreciated about the use of the Access Grid was the academic content. For him the technical aspects were of little concern.

> The lecturer was always so well prepared … I think preparation was what made the lectures a success. The lecturer always knew what he was going to get through and how he was going to do it … The lecture flowed from slides to computing very well and there wasn't any time when we were sitting around waiting for him. There wasn't any time messing around with the computer equipment in the middle of a lecture so the lectures flowed well. Having handwritten slides on the internet [was impressive].

The main benefits of the Access Grid as viewed by these students were, 'demonstrating computer programs during lectures'. Quang commented further:

> We have more time for discussion. We have a better view of the lecture notes. We can interact with students from the other place and that is very interesting.

8.7.2 Surveys: Students at the Distant University

Two students, Phuoc and Anita, from a distant university responded to the survey. They both took the same subject. One of these students was the only one who completed it. The other was among the four who dropped the subject before completion. The student completing the subject suggested 'the Access Grid was not much different from my expectation'. None of these students, however, found using the Access Grid better than traditional teaching. Phuoc gave three reasons for this:

> 1. The student can not physically seek help when he/she is in trouble.
> 2. When the lecturer discusses a topic from the handout or when he points to the whiteboard to explain a concept, I cannot see where he is pointing and this sometime results in confus[ion] and makes the subject harder.
> 3. Lastly, the technology is still poor, sometime we get disconnect[ed] in the middle of class.

Anita preferred traditional teaching because:

> … the students from outside the [host] uni are at a disadvantage because they cannot have one-on-one contact with the professor to discuss problems associated with the class material. The teaching aids, such as booklets provided by the [host] university, were not easily accessed by [distant] students. That is to say, the notes were not always online or available until they were physically posted by the lecturer.

She also noted that because the solutions to assignment mathematics problems were posted, sometimes weeks could pass before distant students would know how well they had done. Local students, on the other hand, were advised almost immediately.

While both students considered they had sufficient mathematics and statistics background to do the subject, the student who subsequently dropped out felt uncomfortable having discussion over the Access Grid. Phuoc had already covered most of the topics from this class, but he felt that if he had not had such previous knowledge, the subject would have been very hard. He did say, however, that he was ‘comfortable’ with the discussion in class. Anita, instead, was ‘not always comfortable’ with discussion using the video camera system. She found two problems with it. First of all, she was conscious that students at another university would not be able to visualise questions that students asked of the lecturer because there was no eWhiteboard provided in her class. Secondly, she felt ‘uncomfortable with voicing [her] concerns and questions’ with a lecturer or students whom she did not know.

From a technical point of view, both considered that they could read everything on the screen, in terms of mathematics or statistics formulae. Anita, the student who did not complete the subject, commented however about the ‘many technical difficulties’ and in particular when ‘our line would drop out and we could not see the main class at all’.

In terms of what worked well for these students, Phuoc recognised the experience as new and really interesting but demanding. Anita recognised the effort made by the lecturer to make things equal, but the issue of distance remained:

> The lecturer tried his best to ensure all students had equal benefit, however the sheer distance between the [host] campus and base university [where the subject was given] made transferring documents such as assignments, lecture notes and solutions too difficult to maintain efficiently … there was discomfort in asking questions from the receiving sites to the other site.

Phuoc did not find the distance a problem, 'it is the same thing as any other class'. For this student, who completed the subject, the biggest problem was, indeed, 'with technology' but he only needed to contact the lecturer 'via the email' to resolve his difficulties. While for Anita the communication aspect was problematic:

> Unable to ask the lecturer for help in person, questions during the Access Grid time were not easy to ask, it was hard to determine if the level of Maths over the 3 unis was equal … Finding a common time to discuss issues was too difficult so I eventually dropped the subject within 3 weeks of starting it.

Interestingly, Phuoc and Anita were from the same distant class but they perceived the technical aspects differently. They were asked, 'Do you have any experiences with the technical part of the Access Grid? For example, difficulty with video, echo on audio, sharing data, connecting to a venue (such as firewall or multicast problems), not being able to see some participants (e.g. too small in the video window or not on camera)'. For Phuoc it was 'Yes', and interestingly Phuoc was the only student or staff member who indicated he would wish to learn to operate the equipment. Even Anita was forgiving of the technical problems, stating that she felt the technology was 'of high quality' but she noted that 'from time to time' it would drop out and a technician had to be called to 'fix the problem'.

There appeared to be no difficulties in the sharing of data files or packages. The lecturer of these students checked whether the slides worked for both universities. Similarly there were no problems with the synchronisation of the audio and video: 'It was good, no problems there'.

Interaction with the instructor was 'very comfortable', for Phuoc while it was the communication aspects which caused Anita to drop out. Interaction with other participants at the host university and the other universities was again 'quite easy' for Phuoc, but 'difficult' for Anita.

For Phuoc, the main benefits of the Access Grid were that ‘students can have more choice on what they want to study’. This was true for Anita as well, but it remained a theoretical perspective and she commented:

> To combine all students interested in the subject across the nation together. It is a great idea in theory but very difficult to implement successfully.

Certain aspects of the technology, however, impressed them both.

> Phuoc: The level of interaction was higher than what I expected.
>
> Anita: The microphones connected to all universities.

Only Anita responded to the question ‘What least impressed you about the Access Grid technology in the session?’. She felt that the biggest problem was that the distant university was unable to have access to documents at the same time that the class at the host university did.

From the perspective of the distant student, the physical layout of seats for the Access Grid was ‘very good’, and they felt that ‘all students and teachers were visible’. The strategies that these students suggested for improving the Access Grid experience involved the provision of resources. For Phuoc, ‘more guidance such as through a textbook for the particular subject or something like that’. For Anita:

> Better access to notes, the ability to send all documents electronically and receive them electronically. Uni[versitie]s should provide this sort of technology to all the students in the Access Grid classes so there is no disadvantage to students who do not own such advanced equipment. A quick lesson on how to use fax machines, scanners, and all other technology should also be provided to the students and lecturers involved.

8.7.3 Student Experience Learning from the Host University and the Distant University

Steve, the student who was interviewed on the Wollongong campus, offered far more comments that the other students who had been surveyed or even the other student (from Melbourne) who had also been interviewed.

In part, this was because Steve completed one subject, as a distant student, which was delivered from a PIG at the host university and a second one, as a local student at the host university using a room-based node. The following is based on his comments in regard to both experiences. This student found little difference between completing a subject through the Access Grid and normal/traditional teaching. He did not see much difference between the two modes. The biggest potential problem he identified was not having a lecturer to go to with problems or questions. When he did a subject on the host university, he felt he could see the lecturer at any time. This was different, of course, when he did one by distance, however this was not a problem because he did everything 'by email to get answers and … the lecturer … gave me his phone number'. He commented that because he did not 'have anything that had to be resolved really quickly, so that wasn't a big deal'.

This student was able to provide perspectives on:

- learning from a PIG, as a distant student, and room-based node, as a local student,
- differences in being at the host university or distant university,
- the adequacy of equipment,
- organisational issues for distant students.

8.7.3.1 Learning from a PIG and Room-Based Node

There was a lack of visibility with the use of PIG, in a distant university, although this was not considered problematic. Steve noted that he could only see the lecturer because there were not separate cameras on the lecturer and on the students and that it led to some uncertainty as to the number of students at the host university. This was an issue also noted in comments from students using the room-based node on the Access Grid. Steve described the subject as having perhaps 'about 6 people at their end', but he did not know how many of these were doing the subject for assessment and how many might have been 'just attending there'. At the distant university, there was Steve and then another student joined, perhaps four or five weeks into it, having transferred from other subjects, making a total, Steve thought, of eight weeks. He commented further that not all the weekly lectures were given due to the absence of one of the lecturers. When that happened, the students completed the subject by doing ‘a large assignment and projects’.

Steve saw the room-based node at the host university ‘about the same as any other lecture’ but he described the lecture as just ‘writing stuff’ and talking. There were notes to accompany the lectures which he could either collect on the day or read beforehand and the lecturer at the host university would ‘explain and demonstrate’ so he felt that as a host university student, there was no difference between this subject and any other. On the other hand, however, he noted that perhaps it might be different for students accessing it through the Access Grid and in fact, he noted that the distant students were ‘really passive recipients’. He thought they ‘weren’t very interested in it’ and that ‘there were only about five lectures that the lecturer gave, possibly only four very short lectures and the rest was based on the project work and assignments’.

In contrast to the room-based node, Steve indicated that he needed to be a little pushy to take part in the interaction when using a PIG, because of the lack of visibility. However, this did not appear to faze him. He was happy with the discussion, but because they only had one camera and one projector at the other end, he was aware that the other students were unable to see him, and felt that when he needed, for example, to ask a question, he would have to ‘sort of verbally jump in’ and be a bit ‘pushy’ because the circumstances meant that he could not simply raise his hand and wait to be called upon. He also commented that he could only see the lecturer but not the other students and he would have preferred to be able to see everyone.

According to Steve, for distant participants access via a PIG was similar to the room-based node at the host university subjects ‘except that all the material was prepared beforehand’. He saw the teaching as a matter of reading and explaining already-prepared slides using the VNC viewer. LaTeX notes were used rather than PowerPoint or Word and that meant that ‘you can just put that up on the screen and scroll through it and you have the equations and the notes and you just talk about it’ without any need to write. He was impressed by the technology which enabled the lecturer to open up computer applications like Excel and show the students, screen by screen, how to work with it and even how to take the results and move them across into SPSS and ‘you can see everything as it was being done’.

The Access Grid was the preferred set up for Steve as he could see participants and the microphones setup was also better. He did not like the feeling of being the only person there in front of a ‘sort of talking head on the screen’. He thought it would be better to be able to see the other students and ‘gauge the reaction’. He also mentioned that the VCN viewer crashed frequently, even more than once in a lecture, and that meant, of course, that he was unable to see the lecture notes. He did comment, however, that ‘I could just get up and go to see the computer and turn it back on again’ but he noted that if the video or the audio cut out, he ‘wouldn’t know how to fix it’ and that was a bigger problem. Steve also complained that he often could not hear students who were accessing via a PIG due to their microphone set-up. He could not hear when they asked a question and would have to ask them to repeat it. The microphones in the room-based node did not cause this problem because they seemed to pick up everyone in the room and they could be heard well at the other end.

Although there was one advantage to being a student at the distant university when using a PIG.

> … when they are not able to see me, you don’t have to be worry about you just sort of move around or theoretically I could have got up and walked out.

8.7.3.2 Differences at the Host University and Distant University

For this student there was no real difference between being at the host university or at the distant university. He said, ‘it is just as good as or almost as good as being face to face’, but he did put some of that down to often being the only student at the university since ‘the other student didn’t turn up pretty often’. He felt he could always get his questions answered and see what was going on.

In response to the question, ‘Did you have enough mathematics or statistics background to do the subject and to have a discussion about the subject with the others at both ends?', Steve thought he had enough background for both the subject he did at the host university and the one he did at a distance.

8.7.3.3 The Access Grid: Adequacy of the Equipment

The lecturer's handwriting could be problematic, an issue compounded at the time with the equipment used. When the Mimio was not working, the document camera was used and that meant that the resolution was not always optimal. In addition, Steve commented that he found it difficult to read the lecturer's handwriting, but he felt that he could always ask 'if you were not sure about it, particularly more about symbols'.

The movement of the writing off the screen when using the document camera could be a problem too because frequently the lecturer did not realise that he was writing beyond the screen capture area and would need to be reminded by the student(s) at the distant university to 'slide it up'. That would not be a problem as long as the eWhiteboard was working.

Steve was one of the first students involved in the Access Grid classes. In the initial stage, reliability was a major issue. In fact, the student commented that he missed three lectures because it 'just didn't work'. He also felt that communication was a problem.

> For example, I had an assignment due today I haven't heard from [the distant lecturer] for a week so it's like a paper assignment and I don't know who to fax it to, who to mail it to, so I handed it to the secretaries to they hold it in so they could sort of say yes it was handed in today.

8.7.3.4 Organisational Issues for Distant Students

Steve recognised two organisational issues that could have an impact on him. If honours students' marks are not in on time, they may miss the opportunity to apply for scholarships for further study.

> Hopefully, I found out where to send it before the mark was due otherwise it wouldn't be marked and wouldn't have the results by the time I need them. I was hoping that it would be resolved. So it's not the actual technology it's more just the difficulties organising things between two different institutions.

Students, particularly those at the distant university, need to know how and where to submit assignments and perhaps to receive some validation that they have been submitted successfully.

The diffusion of other information also requires some sort of system. Provided that is accurate and up to date, online information would be useful, as it is familiar and readily accessible to students across universities. Unfortunately, however, information that students expect to be part of the subject outline, such as the list of assessment items and when they are due, had not been posted properly on the WebCT site, or was accurate at the time of posting, but not corrected later on when the lecturer made changes. Of course none of this is the result of the technology, but rather of individuals' (mis)use of it.

Steve likened the experience of the distant subject to the experience of a host university student who did not go to lectures and relied, instead, on the WebCT.

> … it's just like if you didn't go to the lecture and you don't talk to the lecturer and you don't get the information when it's the time the assignment is due. It's just feels like when a student tries to do a subject just by getting all the information of WebCT and then goes through the lecture. I think that's the same thing as me trying to do it via the [distant university].

Steve had no difficulty with sharing of data or files,

> Basically I could see everything on the screen. So there wasn't actually any data being shared. So if I actually need to get stuff from them, they just emailed it directly to me. The lecturer's organisation averted some difficulties.

At the beginning of the subject the lecturer sent Steve a CD-ROM with all the lectures notes on it. According to Steve, this was because it was impossible to upload all the files onto the website at one time and uploading them individually was too time-consuming. The student thought this could be a problem if 'someone wanted to keep sending lots of stuff' and that perhaps someone should find an easier way of uploading.

The main problems Steve experienced learning from a PIG were technical and he was not sure whose fault they were. He indicated that there were fewer problems as time went on. Technical problems included actual connection, viewing of slides and audio. Connection problems led to his missing whole lectures. Steve felt he was able to catch up but that in some subjects that would be ‘pretty disastrous’. As mentioned above, he found audio problems because of the host university students’ use of a PIG. Another problem which Steve experienced was that he was unable to present a PowerPoint slide presentation.

> For whatever reasons that couldn’t work so I had to email my slides to them. They had to show my slides and I had to ask them politely when I wanted to change the slides. Because we couldn’t send it from our end but we could get it from their end.

Steve considered the video quality to be fine but using a PIG called for some alternative strategies when students were presenting.

> One of the students had overhead slides. So the only way for me to see his overhead slides was the hint to put the overhead slides up on the wall and put a camera on the image and even that I could read. But his overhead slides were very small print. So that was more problem with his presentation than the technology.

There needs to be some training for technical staff, academics and students. According to the student, when things crashed, often no one was familiar enough with the technology to know what to do, but he felt that over time, everyone ‘will be able to pick up a little bit, just the basic stuff and how to fix the most common problems’.

Early on Steve created his own backup strategy. He was very worried but he ‘knocked on doors until things [got] done’ and he even talked to the Head of School. He was assured that rescue would be at hand even if ‘worse came to worst’ and ‘everything fell apart’. This calmed his worries and he settled down and did his best.

Steve saw potential problems for the Access Grid,

> I think that it would be really difficult if you had, say, connected it up to five universities and it is being delivered from here. There is only so much flexibility you can have.

However, he also remained rather positive about the future of the Access Grid. He thought it would get ‘better and better’ as people become more familiar with how to use it. He saw it like any computer application or any technology which takes a bit of time to get rid of the bugs in it and ‘get it working efficiently’.

Steve reflected on the type of problems that could occur for some distant students and for some types of subjects when students need help. For example, he cited a statistical consultancy subject in which students must sit in on a consulting session. He did not think such a thing could be arranged using the Access Grid.

Like many others, for Steve the main benefit of the Access Grid was the provision of greater subject choice.

> I couldn’t find an appropriate 400 level or honours’ level one. That choice thing is really a pretty big problem.

Steve indicated that he was impressed about the whole Access Grid technology package. He said that, having done a computer science degree, and using the internet all the time, he is very familiar with the use of Webcasting and other online technology, but he was impressed with:

> the hardware, the way you’ve got 5 remote control cameras or whatever you’ve got with the computer. That is a big step up from the tiny little Web camera on top of your own computer with a little microphone to sort of expand … up to the point [where] you can do an entire lecture.

One suggested improvement was for the Access Grid room to have a telephone so that technical staff can be called in the event of a problem. This change has been made at the University of Wollongong.

8.8 Academic Staff Evaluations

Three academic staff, Lecturer A, Lecturer B and Lecturer C, two from the University of Wollongong and one from La Trobe University, were interviewed or surveyed (Appendix 15).

The instructions for the protocol were as follows:

> The purpose of this survey is to evaluate the effectiveness of the Access Grid which is used for teaching and learning mathematics and statistics at the University of Wollongong. Lecturers will be asked to answer questions. The following are samples as questioning will be directed by lecturer responses.

The first set of questions involved a clarification of the subject taught, the host university and distant universities that were receiving the subject through the Access Grid. Lecturers were asked:

- Would you please clarify the name of the subject/subjects that you've taught? With which university/universities you shared the subject? How many students did the subject?
- Were the students at the university enrolled in the subject or did they simply attend some of the classes?

The three lecturers represented three subjects being taught:

- Subject 1. This was taught from the University of Wollongong. There were eleven students from the host university, one each from the University of South Australia and RMIT University.
- Subject 2. This was taught from the University of Wollongong. There was one Honours student and one Masters level student from the University of Wollongong. There two postgraduate students from La Trobe University who were taking the subject out of interest but were not formally enrolled in the subject.

- Subject 3. This was taught from La Trobe University. There were ten students from the host university, and two from the University of Wollongong. The distant participants just went to lectures out of interest; they did not do any assignments.

8.8.1 Experiences of Traditional Teaching versus the Access Grid

The lecturers were asked to compare their experience of teaching. They responded to the questions 'Do you think teaching any subjects via the Access Grid is *better than*, *equivalent to*, or *worse than* normal/traditional teaching? Why?'.

The reactions to the use of the Access Grid were in some ways inconclusive, perhaps recognising that although they had used the Access Grid they had not yet explored its potential, continuing, in fact, to teach as they always had.

> I believe the first year that the Access Grid room is used, it is used to teach in a traditional manner and everybody just gave the kind of lecture they would give if they were giving the lectures to students in their own universities. Nobody took advantage of the facilities the Access Grid offers because nobody knows what these facilities are. … came to see me this morning and we talked about that and he wants to have a training session next year to explain the things you can do using the Access Grid room that you can't do in a traditional lecture. I was thinking in the future the Access Grid room will offer a different environment to teach. It will have certain advantages and disadvantages and I am not sure I would say it is better or worse than traditional teaching it is just … the opportunity to teach in a different way (Lecturer A).
>
> Obviously teachers would need to be taught what the advantages and disadvantages are via the Access Grid room. So in order to teach via the Access Grid room and develop skills we need to have training on what you can do through the Access Grid room what you can't do in the normal lecture (Lecturer A).

One of the three lecturers found the notion of evaluation more appropriate when comparing the Access Grid with videoconference technology.

> It was not as good as teaching a normal course. It was a constraint. It does not add anything. Apart from it enables the sharing. The question should be posed in what way does it differ from a normal audio visual, videoconference. There are lots of constraints. Firstly there is the format of the classes. The critical thing is student involvement. I like to have students

> participate, going to the board, writing, interacting. There is a reduction. When you write there is not full clarity. When you speak there is some loss. The second thing - You are physically constrained, around the central document and the Mimio board. The classroom is restricted. The use of the equipment does take training. There is greater freedom in a classroom, if you want to you can go outside. This is a constraining environment. You have this set up. Third is the amount of preparation. It took a lot of extra preparation to make it work. In a normal lecture it is not so polished (Lecturer B).

8.8.2 Evaluation of Technical Aspects of the Access Grid

The Access Grid involves several technologies and different media streams. Lecturers were asked for their evaluations of each of these. The third area of questioning related to lecturers' experiences of the different technologies accessible in the Access Grid. Lecturers were asked:

- What is your experience of the teaching via the Access Grid? What worked well and what did not?
- Do you have any experiences with the technical part of the Access Grid? For example, difficulty with video, echo on audio, sharing data, connecting to a venue (such as firewall or multicast problems), not being able to see some participants (e.g. too small in the video window or not on camera).

Overall Use of the Access Grid

To the question, 'What worked well and what did not?', two lecturers focused on the technical and the other lecturer on the student, response:

> The remote connections worked well once established. [One] problem area was getting connection established (Lecturer C).
>
> One problem was technical, with the Access Grid room [connection] falling down or the sound falling down or the eWhiteboard not working and those kinds of problems you expect the first time you use new technology. I predict that the next time the Access Grid room is used, those problems will be less severe … The first time you use a new technology you anticipate having various problems. I don't think these problems would happen in the future (Lecturer A).
>
> I ran a student questionnaire. Students perceive the room differently. We had a cohort of Vietnamese students who thought this was wonderful. Partly it was the exposure to the latest technology. They are mature and all

> teaching back in Vietnam. It was the opportunity to see a room like this function, not directly for the learning of material but as an experience in itself. Most were positive, they felt the Access Grid room functioned well and they liked the experience with the other university. The student who gave it the lowest rating focused on mathematics, it did not facilitate mathematics (Lecturer B).

Document Camera/Viewer for Teaching

One of the lecturers had not used the document camera, one had. Further experimentation and feedback from preparation for the use of the Access Grid room at Wollongong led to the conclusion that the document camera was not of suitable quality to display some handwriting. This finding is encapsulated in guidelines for presentation. One lecturer described some of the problems and provided his strategy for dealing with the issues:

> [There were] problems about writing at the top and at the bottom of a piece of a paper as these are not projected and sometimes you need somebody to point out to you what they can't read. Once you get used to using the document camera then you start to look at the image to see if they can read it or not. There are problems to do with … can people read your writing with the resolution of the images, but again I think that is a problem that can be overcome if when you're writing using a document camera you also look at the images projected at your university. There was one occasion when I wrote something that wasn't very clear on the image projected in … [the host university] so I asked the students at … [the distant] university if they could read what I'd just written and they said: 'No'. So you also need to encourage the students at the universities to tell you when they can't read what you've written (Lecturer A).
>
> I did not like the document camera. I saw it used and did not like it. It was clear but such a small space (Lecturer B).

Mimio Whiteboard

The three lecturers had used the Mimio whiteboard, and the reactions varied:

> Overall not great … Writing on the eWhiteboard (e.g. often spurious lines would appear) … I am a lecturer who likes to do a lot of whiteboard-based discussion, but this is quite clumsy with the current Access Grid set up … Even without that problem not as much space and freedom for whiteboard writing that I would like. The only advantage is the option to save all lectures in PDF files (which I did) (Lecturer C).
>
> The Mimio in the University of Wollongong didn't work. I am not quite sure if it works at the moment. I think if I was doing a course over several

> years I would use the overhead or PDF files to present information rather than using the document camera and writing things down (Lecturer A).

> From my perspective, the Mimio worked really well. People could download materials. I was disappointed the Mimio was quite difficult. Females found it difficult to press the pen hard enough …The amount of board space is important, two side by side and three high desirable. You have to write bigger, so effectively the Mimio is a small board. But you are able to toggle back to earlier pages … Here we use the Mimio all the time. The students jumped up but they are more passive on the receiving end. Students there did not use the system the same way. They had a different layout (Lecturer B).

Audio

One of the lecturers found the Vietnamese, female students 'had very soft voices' and they could not be heard at the distant university. Otherwise lecturers considered the sound to be good.

Data Sharing

It was clear from some students that the sharing of files had occurred successfully. Not all lecturers had trialled all facilities.

> I didn't use the computer to share data. If I had more time to develop lecture materials, that would be something that I would look into. In the kind of course I teach, computer software is used quite a lot and it would be interesting if you could show students in all locations how to use it using the Access Grid (Lecturer A).

Lecturers and students appeared to be reasonably tolerant of faults in the technology. In the future, it is hoped that quality assurance processes guarantee a better level of performance. Bell (2006) posed the rhetorical question:

> - Ever had a session where:
>   - IT took ages to finally get everything going
>   - The audio was terrible (and people walked out)
>   - The whole session was a complete failure and a waste of time
> - This in turn makes the Access Grid technology look bad, when in reality, it wasn't the technology but how the Access Grid was configured (p. 8).

8.8.3 Communication

Lecturers were asked about the adequacy of communication:

- Have you had discussion with students in both universities similar to normal classes?
- Were you comfortable having discussions with both ends via the Access Grid?

For Lecturer B these evoked a positive response. He was comfortable with the communication. One responded enthusiastically, ‘comfortable, really good, real contact. The quality of the setup is such that you can get a reel feel for mannerisms’. They very ‘quickly got in email contact’. But the distant students were not doing assessment and he imagined that if they were, there could be problems. This lecturer considered that the Access Grid ‘reduced the amount that I could get the students to participate’, compared to traditional teaching. Lecturer A suggested there were no problems:

> I didn’t have a large number of discussions because of the format I was using in the lectures and also because the students at the other university weren’t being assessed. That meant that there was no point in discussing the assignments because only the University of Wollongong students attempted the assignments … I didn’t have any problem interacting with the students on my side because it’s just like a normal lecture and when I needed to ask questions, there weren’t any problems. Teaching again, I would have more interactions, so I guess that might change.

Clarification by the interviewer later shed light on the communication. Reflecting his answer back to the interviewer, she asked:

> … that means the two students at the distant university didn’t ask you questions via email or telephone the way the other students on [the host] university do when they have questions – they knock at the door and ask. Because, those students at the distant university won’t be assessed and they just attend the lecture.

To which the lecturer responded:

> Yes, I think if I was doing a course more than one year I would ask all the students to do the assessments and that I would have more examples in the class and get the students to do the examples in the class, including those at

> the other universities. There is an issue there how much time you spend to design a course if you might only teach the course one year (Lecturer A).

8.8.4 Reflections on What to Change

Throughout the responses lecturers reflected on what they would do differently. The changes included ‘requiring that participants be enrolled and completing the assessment’. As one lecturer indicated,

> I probably wouldn’t be happy about teaching a course using the Access Grid room again if the students at the other universities don’t do any assignments (Lecturer A).

When students were engaged in assessment activities they were full participants in the process, whereas people simply sitting in were not involved in the same intellectual growth.

The second reflection involved ‘increasing interaction’ as one lecturer had identified the sense of restriction that he experienced in terms of constraints on student interaction. The need to increase interaction was also recognised by one of the lecturers.

> If I was teaching the course a second time a course I would make it a little bit more interactive course with more discussions with students. I did that a little bit but not as much as I probably would do. Doing a course over several years would allow me to make it more interactive kind. Also this course was based on the way that I’d taught in the previous years at …University, which was to give lecture notes to the students and get them to do the exercises, coming back to see me when they had any problems (Lecturer A).

The third aspect reflected upon was ‘advance preparation’. At least one distant student had felt disadvantaged by not having access to materials at the same time as the host university students. Another student framed the success of the subject in terms of the academic preparation made by the lecturer. Lecturer A recognised that with advanced preparation,

> You might give your lecture notes out ahead of the lecture and get them to do examples ahead of the lectures or examples to do during the lecture.

8.8.5 At the Host University or at a Distant University

Lecturers were not really aware of the differences for students at the host university and those at a distance. They were asked the questions:

- Do you think is there any difference for students at the host university or at the distant university? For example, when you are teaching from here for students at the other end.
- Do you think if students do a subject via the Access Grid they will get similar results to students completing it in a normal class?

To these they responded:

> Probably there are differences but I haven't been in the position of a remote student (Lecturer C).
>
> Provided the students tell you when they can't read or they can't hear what you've said, then I don't think there is really any difference between students at this end or at that end. The only difference would be if you've got an example and you get the students to do it. At the [host] university end you can look over their shoulders to see what they are doing, whereas for the other universities you can't check the calculations or see what they are doing. If you have students at other universities, they might be able to use the whiteboard at their universities and you can use the camera to see how they are doing the calculations. If you've got small classes it could be quite interesting because you might have two whiteboards at each university. You might have a situation where each student can look at each other student's whiteboard. Even with the whiteboard at a different university, then they would be able to ask each other. A student at … [the host university] might have a problem and you could stop the class and everybody could look at the student's whiteboard and provide ideas. So I think the differences between the students at the receiving and the transmitting end are quite minimal, but there would be small differences (Lecturer A).

One considered that results would be different:

> They certainly will. At 4th year level one of the great things is being personally involved, so it is possibly not as good as a normal course. It is a good product, what do you compare this with? The Access Grid at 4th year level could be compared with AMSI [Australian Mathematical Sciences Institute] subjects. They are also a little bit restrictive. Often for the AMSI courses the assessment is not completed at the time. They are not a normal course even though in a room with normal teaching methods. There is not

> the same control over assessment. At least the Access Grid has the potential to be as good as or better than the AMSI course (Lecturer B).

8.8.6 Teacher Preparation

In response to the question, 'How does the preparation time and preparation style for the lecture in the Access Grid compare with normal/traditional lectures?', the lecturers all indicated that the preparation was at a higher level than would otherwise occur for a fourth year subject.

> It is a bit higher for two reasons
> (1) Need to arrive earlier to get set up - depending on technician help available
> (2) Processing assignments of remote students takes time (printing, posting etc) (Lecturer C).

> I think the way that the Access Grid was used this year there is no difference between an Access Grid lecture and a traditional lecture, because the lecturer didn't really consider those aspects of the teaching which could be changed to use the Access Grid. In terms of teaching materials, I always put my teaching materials on a webpage. Usually this was just before the lecture, but in principle the students could print them off from the webpage or look at them on the webpage as I use them … I've also thought that if I was teaching the same course in more than one year then I might develop things like overhead or PDF files and I'll use those instead of handwriting. When you're teaching a course for one year you don't know you might be teaching in the future, it is difficult to find the time to develop the resources more appropriately. I think there is an issue that has to be considered by the Head of the department, that if people were going to teach using the Access Grid for more than one year, then they might develop resources and materials that better use the Access Grid (Lecturer A).

> When you have a big first year class it is very time consuming. But I am not convinced that this is the same for a very small group of 16-20 students. It is also at a high level. You never give the same 4th year course. They are partly research. A Grid room subject at 4th year is more demanding on the lecturer (Lecturer C).

8.8.7 Organisational Issues

There are organisational issues to be considered when sharing subjects between universities. Two specific questions were asked but observations appeared throughout their surveys:

- In teaching a subject for 300 or 400 level, what's your opinion regarding how to deal with teaching the subject to the students at different universities having different backgrounds?
- Do you teach them some topics and refer to those topics which are prerequisites? What do you do for those subjects if you want to teach?
- Is there any thing else you would like to tell me about?

In response to these questions, the lecturers raised several issues that needed to be considered when delivering subjects through the Access Grid. These include:

Background Knowledge

Inadequate student background did not appear to be of major concern or the lecturer had a strategy for students to detect their inadequacies early.

> I don't think it is a problem for the course that I teach because I don't assume that they know anything more than first year calculus, which is pretty similar in most universities. They also need to know a little bit about eigenvalues, so for my course it is not a problem because the prerequisites are so minimal. But it is definitely a potential problem for other courses. You might have to think about providing lecture notes covering the material from courses taught earlier (Lecturer A).
>
> It is important to have assignments early on to convey the level of difficulty of the subject (Lecturer C).

Textbooks

One lecturer drew attention to the textbook issue where a distant student did not have access to a textbook as it was not held by the library or bookshop.

> … if you are going to have a course and you are going to have recommended textbooks, then you need to make sure the other university has those textbooks. It means telling the other universities in advance so that if they don't have the recommended textbooks, then they can order them for the library (Lecturer A).

Structuring the Subject

The start of session varies for different universities although this did not appear to be a real problem for these lecturers.

> … University starts their sessions one week after us. That's not really a problem because I don't mind teaching a course in 12 weeks. For my course there are lectures for about 6 or 7 weeks and then there are projects for the students who did the projects. So if we lost a week it didn't matter too much. If I was doing the course again it wouldn't really worry me because I can make the projects shorter (Lecturer A).

It is better to have as few sessions as possible given the set-up costs. Ideally a tutorial-type session would follow the lectures during which the hook-up would still be open.

> At Honours level, the schedule can be flexible. There are end-of-session constraints. It is critical in terms of when students hand in their theses. They should finish early, so there is time to finish theses. You do not want them to still be putting in assignments. For La Trobe this is mid-November, at Wollongong it is earlier. It is a real issue. It is very stressful for Honours students. AMSI run two-week intensive courses, four weeks is more leisurely. The Access Grid subjects do not need to be full semesters. There are more constraints on 300 level students. Ten assignments on a weekly basis, a week off at the start, a week off in the middle, it may be best to experiment with the structure (Lecturer B).

Assignment Submission

While the lecturers coped, it was clear that at some point, the system for the submission of assignments might need to change.

> Assignment submission from remote students should eventually have stricter and clearer protocols (Lecturer C).

Backup Strategies

Discussion in the setting-up phase and implementation often involved suggestions for back-up strategies. Capturing the sessions was not an option. There was some concern over this as expressed by one of the lecturers, 'No strategies at all, I think this will be a real issue, when we start having students enrolled at other universities [rather than sitting in]'. A second lecturer noted that he could, 'post lectures and other material on the internet'; although from the perspective of equity this might not represent an equivalent resource to being able to take part in the teaching session.

Training

There are two aspects to training: the technical and the academic. For one lecturer there was a need for a detailed manual with every step of the connection process clearly explained. Ideally the connection process is streamlined to be as simple as possible. There was also recognition that more staff needed to be trained, and to become involved. When asked about operating, however, no one at this stage wanted to operate the equipment.

Preparation

Students indicated that they needed access to the materials at the same time whether they were at the host or a distant university. From a distribution perspective, use of a webpage to distribute would be preferable to emailing files, as this lecturer commented.

> Obviously if you are going to hand out materials to the local students, you also need to distribute them to the non-local students. If I was teaching again, I would try to put PDF files a week ahead of the lecture on the webpage (Lecturer A).

8.8.8 Improvements for Better Teaching

The possibility of the lecturers controlling the equipment was examined and ways for improving the facilities were canvassed. None of the lecturers wanted to operate the equipment. One found the layout of the Wollongong room adequate while the other suggested a larger room would have been better.

> With current space, it is hard to see alternatives to the current arrangement. Ideally, the room would be 50% bigger so the lecturer would have his/her own bench space (Lecturer C).

> This year I was using the document camera, which was good, because I was looking at the screen and I could see the students. If I moved to using PDF files, it might be different because I probably would be standing in front of the [overhead] projector and I would only see the local students (Lecturer A).

Lecturer B considered the layout *comfortable*:

> … everyone appears to have clear sight. One thing, when the lecturer stands at the Mimio board you obscure student vision. But because they could see the image of the screen, rather than the Mimio board itself, the view was slightly better than normal. I am not sure about when the remote campus has more students. It is difficult to pick up when they are tired, laughing or bored.

However, all had suggestions on how to improve the Access Grid or to use it to help their teaching of mathematics.

> Make eWhiteboard technology closer to the traditional one. Make the connection process simpler for a non-technician. Make it possible for remote students to write on a board and get transferred back to UOW (Lecturer C).
>
> I don’t think it is a question ‘How the Access Grid can be improved?’ I think it is a question of being made aware of what things you can do using the Access Grid that you can’t do in a traditional classroom. Then it goes back to the point that was made when … saw me this morning. He is developing an educational series to show what things you can do using the Access Grid that you can’t do in a traditional classroom. So it is not a question ‘How the Access Grid room can be improved?’, it’s a question ‘How the staff can be made aware of what the Access Grid room can do?’ (Lecturer A).

Two lecturers saw the main benefits of the Access Grid in terms of the potential for sharing:

> Pooling (scarce) resources in the teaching and learning of statistics at higher levels (Lecturer C).
>
> The main advantage of the Access Grid is fact that it can share courses across different universities. So you can offer a wider range of courses to your students. However, as you’ve already mentioned there is a problem ensuring … that students at the different universities have the necessary prerequisite to do any course (Lecturer A).
>
> Once a number of Access Grid rooms are available it will really give the students real subject selection. With smaller departments, enrolment options are reduced. The Grid Room will go some way to redressing this problem (Lecturer B).

The other saw it as a replacement for videoconferencing. This lecturer had experience with videoconferencing and he found the Access Grid, ‘hugely different’. He went on to say that videoconferencing is so poor, whereas ‘the Grid room does make distance education a real possibility’. Although videoconferencing ‘had a simpler setup for lecturing’ it had ‘fewer images’. In contrast, he found the Access Grid ‘had far richer information’. He found the quality of the Mimio ‘really good’ and saw the multiple cameras and multiple microphones as an advantage. The regional campuses at his university were ‘sick of videoconferencing’. Similar comments have been made by staff in the international literature,

> … equivalent to videoconference but with better interaction due to AG room feel – all participants look life size (Daw 2006, p. 7).

8.9 Comparison of the Teacher and Student Experiences

The contrast between Phuoc’s comments and Anita’s suggests that students experience communication over the Access Grid quite differently. For the distant students, there does appear to be an issue with communication, particularly for students who are not comfortable discussing difficulties over video. There are also communication difficulties experienced in terms of providing resources. In addition, lecturers do not seem to detect the degree of discomfort that some experience with communication. Anita’s lecturer was interviewed but provided no indication that there were communication problems. He commented: ‘Probably there are differences but I haven’t been in the position of a remote student’. Anita later wrote to the researcher indicating:

> I put in a lot of effort in the beginning weeks but as time went on it became more obvious the distance was too big a factor to get around, even with the video consultations. I have never dropped a class before, so it was a really difficult decision to make, but ultimately I had to do what I thought would be best for my studies.

For virtually all staff and students, the main advantage of the Access Grid was the possibility of sharing across universities. As one lecturer commented, he had taught as if it were a traditional classroom. There needed to be training to take advantage of the pedagogical features of the room which had largely remained unknown during the developmental period. One lecturer described the training and institutionalisation issues as follows:

> We have one staff member who is learning to use the room. Just in-house. There are two seminar series, learning how to control the lighting and projection. We rely too much on our technical support. We do need to broaden out the number of people involved (Lecturer B).

8.10 Conclusion

The Access Grid project set out to offer mathematics and statistics subjects between universities across Australia. The findings from the interviews and questionnaires showed that overall the project was successful in terms of teaching and learning. Although some deficiencies typical of technology-based teaching and learning existed, the primary advantage was seen to be the students' access to a wider variety of subjects than those on offer at their own university. As one of students Amitabh pointed out, the main benefit of learning via the Access Grid was its capability to connect universities across Australia and therefore access to a greater range of mathematics and statistics subjects. Phuoc also indicated that students can have more options on the subjects that they want to study.

Although Phuoc is a student from a distant university, he was impressed with the level of interaction which was more than what he expected, it is important to ensure that distant students are comfortable with the communication, in particular with discussion over the video component, and that they are seen to have equivalent access to lecturers and resources. Other strategies need to be put in place, perhaps ensuring that all materials are accessible on a website at the same time. It may be that lecturers need to have a web camera in their office which students can use in consultation time from the distant universities.

As teaching and learning with technology is often different (Koppi 1998) from teaching and learning face-to-face, there is a need for some guidance for lecturers teaching with the Access Grid. Indeed, there has been some training and guidance sessions for lecturers and staff to get to know the Access Grid technology and to feel more comfortable with it, but the consensus is that more is required.

At the time of writing, there is no plan to use the room-based nodes on the Access Grid for teaching and learning in other disciplines at the University of Wollongong. However, several schools and departments have expressed interested in it.

Chapter 9

Conclusion

Institutionalising Innovations

9.1 Introduction

In this final chapter it is apt to review what has been learned from the explorations in using technology to improve mathematics education. This is done in the context of Alexander and Hedberg's (1994) model of evaluation, with the final phase looking at the institutionalisation of the innovations. The question of concern is to what extent the innovations have been adopted outside of the sphere in which they were created.

As the research was evolving, while video resources were being developed and trialled, there was a passing of time and the innovations were taken up in other sectors. In many senses, while this particular research has concluded, the vision of what should happen next has moved on. This chapter, therefore, will examine how others at the University of Wollongong want to modify and extend both the processes used to create the video learning resources and the nature of the resources.

Access Grid technologies also continue to develop. The network, initially involving three universities, has extended to nine universities. At the University of Wollongong, however, while the use of the Access Grid to teach to, as well as to receive teaching from, other universities, is embedded, the concept of how to deliver functionalities equivalent to the Access Grid has been further developed.

In this chapter it is also appropriate to reflect upon the perspectives that have changed for the researcher as to how to improve mathematics education through the use of technology. This is timely, as she returns to teach in another country.

9.2 Video Resources - Uptake by the University Community

Just as it was important for students to know about the existence of the video resources, it was also important to spread this awareness throughout the University of Wollongong community. Because of this diffusion of knowledge, there have been two successful funding applications from within the School of Mathematics and Applied Statistics which were based on the work undertaken in this thesis.

- Fundamental Maths: Opening the Gates (Nelson et al. 2005) and
- Summertime Maths (Williams et al. 2006).

Members of the wider university community who had seen the work involved in this research contacted the principal supervisor with a view to working with staff in another Faculty. As a consequence, one further application has been developed and another is in the process of development:

- Developing Mathematical Skills for Science (O'Brien & Porter 2007).
- University Learning Resources: Return to Mathematics (Porter 2007b) for developing mathematical skills and concepts, application requested by the University Deputy Vice Chancellor 2007.

Not only do these projects characterise the success of the video resources from an institutional perspective, the developments also allow an elaboration of the nature of planned future developments.

9.2.1 Fundamental Maths: Opening the Gates

The proposal for the Fundamental Mathematics Project was framed as follows:

> Mathematics is for many students a difficult discipline. It has been described as the *gate-keeper* to a number of professions. This gate-keeping role is often seen as problematic in terms of social justice and equity. The School of Mathematics and Applied Statistics has several subjects on offer which are pathways for students seeking to enter a variety of professions. However, even with the tailoring of subjects to suit different disciplines, there remains the problem that many students are ill-prepared to study Mathematics. Many of these subjects have failure rates in excess of 25% and with this proposal we seek to redress that situation through the development and evaluation of learning resources (Nelson et al. 2005).

The basis of those learning resources, as described in the application, was the video resources created in the early part of 2004 as part of an exploration of technologies for creating resources. The application recognised that the author of this thesis commenced doctoral studies with Dr Anne Porter and Dr Richard Caladine (CEDIR) as supervisors and that *[Mrs Aminifar] has been exploring the use of modern technologies in the teaching and learning of mathematics*. Dr Mark Nelson was co-opted at this stage through the QUALITY101 project and the researcher, with the permission of Dr Nelson, had feedback throughout the development and implementation phase on the appropriateness of the video resources. The application was competitive and won internal funds to assist with production costs such as voice- over.

9.2.2 Summertime Maths

The trials and evaluation of the video resources that were conducted for this thesis in 2005 and 2006 formed the basis of a subsequent application called ‘Summertime Maths’. In this application the concept of how to use and extend the resources was developed. In addition to the supervisors of this thesis, three further members of the school, including the Head of School have become involved. The proposal was framed as follows:

> Maths is taught throughout 12 years of School and students entering University are expected to be competent across this large base, but virtually all students have some gaps in knowledge, and not all in the same places. The CD-ROM [Summertime Maths] will provide students with details as to the specific mathematics skills that each degree, or the entry level mathematics required for different maths subjects, so that students may target the development of specific skills. It will provide learning resources in a variety of media, video capture (not typically available) and written (Williams et al. 2006).

While development of video resources remained central to the project, an extension of resources was required. The scope for combining the video worked solutions with other resources showing the use of mathematics in real world applications was identified:

> It will also provide motivational material by way of 21st century units so that students can see the relevance of mathematics to a variety of current topics in disciplines such as Science, Engineering and Applied Mathematics and Statistics. The CD-ROM will be available to students during the initial formative weeks of their introductory mathematics subjects (Williams et al. 2006).

The timing and delivery of the resources shifted to target students prior to entry to university.

> Moreover it will be made available as a resource for intending students to use in the Summer before commencing Uni. The project is the highest priority in terms of teaching development for the School of Mathematics and Applied Statistics (Williams et al. 2006).

By the conclusion of the analysis of the data (Chapter 6), it was considered that the development of transitional learning resources was inadequate. Instead, students required support throughout the introductory level of study. How to gradually increase students' independence in learning, without relying on lightly structured materials then becomes an issue.

9.2.2.1 Production of Video Resources

Early in the time frame of this research, design decisions were made to trial two production techniques and not to use a third involving a person in the video clip. In Chapter 4, it was concluded that another production technique would need to be found, as staff appeared to find the process too complicated or time-consuming. While the processes developed were ones which both the researcher and casual staff employed could use, there was an intensive learning phase. The Summertime Maths Project involved a new team and the development of video resources passed from the researcher to others. The videos made as part of this research began to be complemented by videos developed for the Summertime Maths Project.

The additional videos were created with the third technique which was originally rejected. However, at that stage there was no evidence to support the decision to 'not include the person'. As can be seen from Figure 9.1 and Figure 9.2 two video cameras are used to film the lecturers as they work through either theory, rules and definitions for theory refreshers, or worked solutions. The film crew then edits the video clips. Two camera shots are available for inclusion, close-up shots and shots from further away. This process was discounted at the design phase of this research on the grounds that the person might be too distracting and that the file size would be somewhat larger. It is also a process that is dependent upon money or allocation of video resources and it is not one that a lecturer can undertake alone. However, it suitable in terms of the academic time-commitment, where it is quick to develop a script and teach several topics in one filming session as long as funding was available.

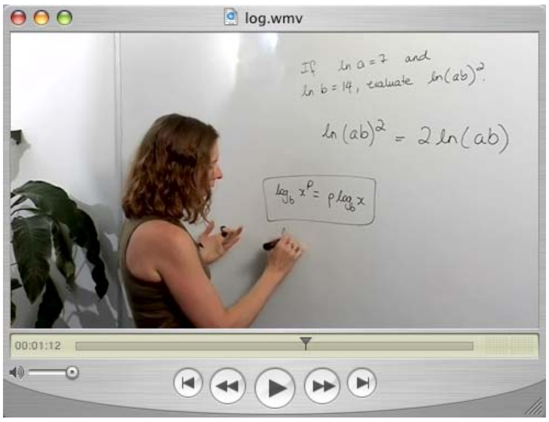


Figure 9.1 First Camera Angle, Distance Shot

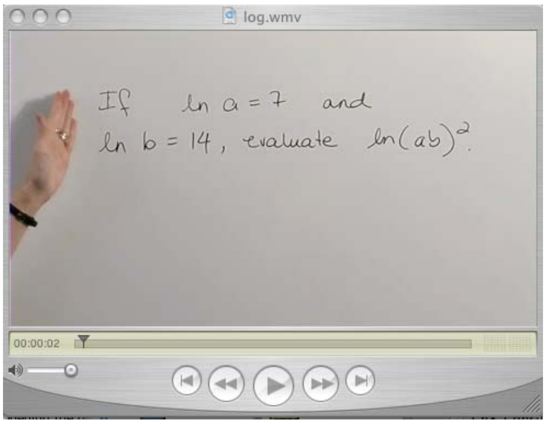


Figure 9.2 Second Camera Angle, Close-up

It was possible to question students about these additional video resources. In 2007, at the end-of-session change evaluation, students were asked, ‘Which approaches, with hand or person, do you prefer?’. Of the respondents in MATH141 to this question 87.8% of students (n = 79) preferred to see video solutions with hand, 5.6% (n = 5) preferred to see video solution with person and for 6.7% (n = 6) either was fine. Eleven students did not answer this question. Overall, then, the presence of the handwriting in the video solution is regarded by students as advantageous.

From the perspective of finding an approach that can be adopted by others, rather than relying on funding, the use of PC tablets could be trialled because these have been described as requiring little time to develop worked solutions with voice-over (Dekkers 2007).

9.2.2.2 Institutional Extension of Video Resources

At the time of writing, the Summertime Maths resources were accessible at:
http://www.math.uow.edu.au/subjects/summer/.

At this stage fewer video resources have been included in Summertime Maths website than were available on the MATH141 website.

Please see print copy for figure 9.3

Figure 9.3 Summertime Maths at the University of Wollongong in 2007

As can be seen from Figure 9.3, the interface anticipates that several mathematics subjects will eventually use the Summertime Maths resources. Each subject has its own webpage, linking to the resources required for that subject (Figure 9.4). At this stage, all the subjects listed require the video resources to be developed. Sometimes they are required as revision material and at other times as resources for new topics.

Please see print copy for figure 9.4

Figure 9.4 One Mathematics Subject on the Summertime Maths Website

Examining the webpage ‘Topic Refreshers’ shows how the work developed in this research has been embedded into this project (Figure 9.5). The primary emphasis in the research work has been to develop and trial worked solutions or ‘worked examples’, as they have now been termed.

Please see print copy for figure 9.5

Figure 9.5 Topic Refreshers in One of Mathematics Subject in Summertime Maths Website

When students select worked examples they are provided with a list of problems which they are advised to attempt and then they have the choice of selecting live solutions or written solutions (Figure 9.6) as originally devised, but with some now involving the third production technique.

Please see print copy for figure 9.6

Figure 9.6 Worked Examples with Three Available Options

9.2.3 Developing Mathematical Skills for Science

A staff member from Learning Development made contact with the principal supervisor of this thesis, suggesting a meeting with a member of the Science Faculty who had an interest in developing mathematics resources for science students. As a consequence, another application was prepared in conjunction with a team from the Faculty of Science, headed by a lecturer in chemistry and the principal supervisor of this thesis. In addition this team included two members from Biological Sciences, one from Earth and Environmental Sciences, and one from the School of Mathematics and Applied Statistics. As the science team recognised the collection of resources was becoming larger and other forms of storage and tagging of learning objects might be needed, they included a member from the library. Two additional members from the Centre for Educational Development and Interactive Resources together with the staff member from Learning Development were also involved.

This project sought to extend the work by providing a science context to the mathematics resources developed. Specifically the aim was to:

> Develop video based learning resources, adapting the model developed by Aminifar, Nelson, Porter and Caladine (2005), to include, science context, definitions, and worked examples, including alternative approaches. Where suitable existing resources are developed for MATH141 they will be used (O'Brien & Porter 2007).

The initial target group was to be students undertaking a bridging chemistry subject. The chemistry lecturer began to experiment with the video production process, but stopped before adding the audio voice-over.

Coinciding with the science application was another request for funding from the Faculty of Commerce, which aimed at developing motivational video resources in statistics. Neither project was funded in the internal competitive process. Rather, the Deputy Vice Chancellor (Academic and International) requested that the principal supervisor of this research develop an application for a sizable internal grant to develop resources to target the needs for mathematics and statistics learning resources across all faculties in the university. The framework provided by the Summertime Maths Project was readily extendable to include additional subjects.

This application is currently under development. It is tentatively called, *University Learning Resources: Return to Mathematics.* The co-ordination structure of this project is multilayered, with virtually all faculties and units such as Learning Development at several campuses and the Woolyungah Centre for Indigenous Students involved. All contacted have supplied either contact people for units, schools or faculties with minimal needs and teams where the needs are greater. A statement of needs is being provided by the teams.

9.2.4 Return to Mathematics: A University Resource

The funding application for the project ‘Return to Mathematics’ seeks to extend the work in the Fundamental Maths Project and the Summertime Maths Project from the predominantly *skills* approach developed in this thesis for students in MATH141 subject.

The team undertaking this project is now in collaboration with two other universities regarding the shared development of resources. Future research will involve the development and evaluation of different genres of resources addressing: concept development, maths in other discipline context, experiencing mathematics/constructing mathematical knowledge, a problem- solving approach and a gaming approach.

> *Concept development*
> How mathematics is taught might focus on understanding the concept or algorithmic procedures or rules for performing the skill. For example, the focus could be on techniques of how to do integration or concepts such as the underlying principles of integration and in addition that integration is useful for finding for instance, area, probabilities and expected values.
>
> *Maths in other discipline context*
> This approach focuses on teaching maths in context with problems couched in discipline-specific language. This approach is favoured for developing students’ ability to transfer mathematics skills to their disciplines.

Experiencing mathematics/constructing mathematical knowledge

The use of visualisations through spreadsheets, animations, CAS and applets is often associated with building understanding through experiencing mathematics. For example, students are able to investigate the impact of various manipulations of lines and shapes that correspond to geometrical and algebraic manipulations.

A problem- solving approach

In this approach students are given a real-life problem to solve. They might not have developed the mathematics skills required, but in the process of solving the problem they encounter the need for mathematics in the solution, and go on to develop the skill required.

A gaming approach

In this approach games are used to motivate students to engage with mathematics.

9.3 Current Problems and Future Potential of the Access Grid

The School of Mathematics and Applied Statistics at the University of Wollongong was successful in attracting funding to develop a room-based node on the Access Grid. The funding was part of a project organised by the International Centre of Excellence for Education in Mathematics (ICE-EM). The project set out to facilitate inter-institutional teaching and learning as many universities had small numbers of students wanting to undertake a wide range of mathematics and statistics subjects. The case study, reported in Chapter 8, was conducted in the early stages of the project when only three universities were sufficiently advanced with the development of their Access Grid Rooms to share teaching and learning.

The Access Grid is based on open source software which is continually being developed and at the time of the case study required high levels of technical support. Support was needed to maintain audio and video connections with other participants and to enable the sharing of computer files and applications.

In addition to the Access Grid software, a room-based node consists of various pieces of audio-visual equipment, including, cameras, projectors, microphones, speakers, computers and computer peripherals. One of the peripherals in the Access Grid room at the University of Wollongong was a device that captured the pen strokes from a whiteboard. The initial device installed for this purpose was of the pen and receiver type. That is, a receiver was placed on the side of the whiteboard and the pens were enclosed in sleeves. The sleeves transmit ultrasound which, when detected by the receiver, is interpreted and reflects the position of the pen on the board. Unfortunately, this type of pen stroke capture device had an intermittent but persistent problem which interrupted the teaching. Due to this problem, a decision has been made to replace the system with a touch-sensitive electronic whiteboard, as this appears to be more robust.

During the installation of the room-based Access Grid node, further funding, this time from within the university, was attracted to install another room-based node at one of the regional campuses. The installation was to enable the sharing of classes between the two campuses.

The use of the Access Grid for inter-institutional teaching and learning was evaluated. Evaluation methods included interviews with, and surveys of, staff and students at each of the participating universities. Two major issues arose out of these trials:

- the need for ways to ensure that students are comfortable communicating and
- the high cost of technical support which has proved an impediment to future expansion.

Despite these issues, there was recognition by all, of the great advantage in being able to share subjects across universities and that there are strategies to overcome many of the perceived organisational issues.

Given that the findings of these evaluations indicated that high levels of technical support would be required at the regional campus in order for it to operate appropriately, the plans to install an Access Grid were modified. In the past videoconferences had been used for communications between the campuses and this was considered as a possible alternative. The sharing of computer files and applications in Access Grid was achieved through the use of Virtual Network Computing (VNC) so a natural extension was to consider the pairing of videoconferencing and VNC. If high definition videoconferencing were used, a single, high definition video stream would replace the multiple video streams of Access Grid and the shared files and applications would be the same.

At the time of writing, additional videoconference technology and VNC is being installed at the regional campus.

Access Grid has been used for research collaboration and, in many cases the participants were skilled in computer sciences and could supply their own support. There are clear benefits to the use of Access Grid in teaching and learning. Like other Real Time Communication technologies, Access Grid can reduce or remove the need for students or staff to travel despite being situated in distant geographical locations. In the case of the project described in this thesis, the use of Access Grid provided the small number of higher-level students in mathematics and statistics at several universities with a far wider range of subjects.

As mentioned earlier, the Access Grid software is open source and continually being developed. Perhaps the continuing development of the software will result in an application that requires a lower level of technical support. This will increase the viability of the Access Grid as a Real Time Communication technology for teaching and learning.

When the Access Grid is used for inter-institutional teaching and learning, a different level of organisation is required. Complications arise when a student at one university takes a subject from another. Assessment results need to be transferred between universities and the distribution of student fees can be an issue unless there is an equitable level of reciprocity in teaching. A new process for organisation needs to be put in place and an expanded time-frame used to ensure that all students, teachers and support staff can be adequately prepared.

The University of Wollongong is now a collaborative partner on a $1.2m project (Taylor 2007). One of the aims is to develop ‘methods and process for its [the Access Grid] use in mathematics education’ by sharing the capabilities of several Australian universities through the use of high speed internet-based communication technology (Access Grid Nodes). It is intended to adopt best practice and standards at the advanced and honours level across Australia.

9.4 Postscripts - Personal

In undertaking a project such as this thesis, the researcher is a participant in the process. It has been a process of incremental change, of working with existing staff and their approaches to pedagogy and curriculum, rather than exploring radically different approaches to improving mathematics. In proceeding in this manner there has been a substantial drop in failure rates and an increase in opportunity to trial and introduce other approaches to improving student learning. Issues have arisen that challenged my perceptions regarding education and the role of technology in improving mathematics education. Most of that focus has been on the development and evaluation of video resources. My tutoring the students in MATH141, however, provided further insights into the use of the resources and caused me to reflect upon the entire process of educating mathematics students.

These reflections revisited the following:

- Mathematics Curriculum (9.4.1);
- Mathematics Teaching (9.4.2);
- Supporting Enabling Mathematics (9.4.3);
- Mathematics Assessment (9.4.4);
- Nature of Video Resources (9.4.5) and
- Embedding the Video Resources (9.4.6).

9.4.1 Mathematics Curriculum

Comparing the syllabus of MATH141 and MATH142 for engineering students in UOW with those in Iran suggests that first-year engineering students learn fewer mathematics skills in Australia than in Iran. Now I am interested in comparing engineering students' mathematics knowledge in second year at university and the impact of this on the other engineering subjects at years 3 and 4.

The undergraduate subjects that I have experienced in both countries are similar in the focus on skills. There is evidence, however, from a wide variety of sources that there are other approaches that focus on students experiencing mathematics (Boland 2002). In adopting the approach for other projects it was also clear that lecturers from other disciplines wanted to extend the resources to cover the use of mathematics in context. For this study, it has been necessary to develop resources for the existing curriculum and assessment system. Indeed it has been an exercise in modifying learning outcomes while working alongside staff who are involved in the teaching of the subject.

As a further postscript, the question of whether the tradition of teaching mathematics should continue with a skills-based approach has been revisited, although it falls beyond the scope of this thesis. In 2007, the School of Mathematics and Applied Statistics commenced a curriculum review of 100-level calculus subjects. Three of the committee of six were involved with the video resources through the Summertime Maths Project. Although that work is not finished, there has been a recognition that the subject needs to address more than mathematics skills, that it should introduce some level of mathematics in context, technology and problem solving.

9.4.2 Mathematics Teaching

To improve the teaching of mathematics I would seek to make changes and evaluate their outcomes. Specifically the changes I would introduce into the teaching are:

- From the perspective of the university teacher, teaching mathematics content to engineering students is different from teaching mathematics content to mathematics students. In the past fourteen years, I have used an instructivist approach to teach engineering Calculus, Differential Equations, Engineering Mathematics and Numerical Analysis. In the future, I would like to use a mix of instructivist and constructivist approaches.

- To find which mathematics topics incoming students need more support on, I would carry out a confidence survey in the first week of session rather than a Basic Skills Test. The Basic Skills Test does not seem to be an appropriate welcome to incoming students at the first week of session.
- Teaching in Australia is different from teaching in Iran. In Australia, there is a mix of domestic and international students who have quite different mathematics backgrounds. Some international students are unable to participate in classroom discussion because they lack confidence in speaking English. I used to approach them in a friendly manner, explaining the problem/s with their answer/s. Some were really ‘sharp’ and just a hint was all it took to enable them to complete a solution on their own.
- To encourage students to start to think critically, I would ask them to find the mistakes in the work of all students. In tutorial class, I would encourage students to do questions on the whiteboard (which they are supposed to do, but some do not like using the whiteboard) so they can learn from each other rather than having students sit and use ‘paper and pen’ to solve the questions. In tutorial classes when I see that students make a common mistake, I would ask one of them if they mind having the other students’ attention. Then I would ask all the students to find the error that has been made. If I get the right answer I would encourage them and if not I would give them a hint to continue and then draw a big cross (preferably in red) next to the mistake. Then I would explain the process of developing the correct worked solution. This is the major benefit in using whiteboard tutorial room.
- Even though the fill-in lecture notes were not the most highly rated resources according to the change evaluations, these seem to be a better system of lecture notes than students have in Iran. The use of fill-in lecture notes in a large class is different from a small class, as I found when lecturing in MATH142 for a small class where I was able to follow-up my teaching by asking students to fill-in the gaps, especially using a worked solution for an example. They were

interested to see what I wanted to say, as they had an opportunity to participate in discussion. To encourage students to listen to the lecturer I would adopt the method of fill-in lecture notes in Iran. I would adopt the approach where the theory is complete and the spaces are for worked examples, discussion and exercises. In Iran in universities where I have taught, students were asked to buy the recommended textbook and sometimes lecturers provided additional lecture notes. The notes had no gaps. It is common in Iran for students who have access to these resources, to still copy everything from the white/blackboard at the time of teaching, as sometimes there is some discussion or extra examples. In fact, the same thing sometimes happens here when some worked solutions for examples are used which were not included in the fill-in lecture notes. The fill-in lecture notes in addition to the textbook and lecture notes would be useful.

- In MATH141 lectures, students do not write anything on the whiteboard. Here the lecturer writes on the whiteboard and also manages the class and students. Students only have the opportunity to work on the whiteboard during tutorial class. An experience that was interesting for me was the opportunity to lecture MATH142, the follow-on subject. I gave students ‘integration’ questions from past exams and asked them to solve them. Then I asked if anybody would like to come and evaluate the ‘integrals on the whiteboard. Students were happy to do this and I felt that they really like it. This is something that I would like to trial and evaluate in Australia as it is common practice in Iran. Students then asked to come and solve it on whiteboard. They felt confident enough to do this in front of others. I believe that this is different from a tutorial class. In a tutorial class, all students have the same opportunity, but in this environment I felt that students wanted to participate and compete!!

9.4.3 Supporting Enabling Mathematics

The Enabling Mathematics subject has provided opportunities for students to enter engineering degrees; however, it appears that a ‘Pass’ or, even a ‘Credit’, performance is not sufficient to prepare students for the follow-on subject. There is evidence that the video resources in MATH141 are associated not only with an increase in passing grades but that there is also a shift in grades to the higher levels suggesting greater skill acquisition. From the Return to Mathematics Project (Porter 2007b), the lecturer of MATH142, the follow-on subject to MATH141, has requested as a higher priority than resources for MATH142, resources for basic skills of an even lower level than those revised in MATH141. While students may understand the new topics they encounter, they still lack basic skills. Again the lecturer's emphasis is on enabling skills as it was for the lecturer of MATH141. In this research, the development of fundamental mathematics skills was not considered sufficient. Rather students were seen as needing learning support throughout the entire subject, and this meant support for students as they encountered new topics.

9.4.4 Mathematics Assessment

The change evaluations revealed that students found the Basic Skills Tests and Mid-Session Test contributed less to their learning and understanding than did the other forms of assessment, namely, fortnightly assignments for regular students. According to the coordinator, the Basic Skills Tests were not designed to contribute towards students' learning. Rather, they were summative assessment tasks the purpose of which was to motivate students. In addition, students who obtain a grade of less than a credit in MATH141 have a high risk of failure in the follow-on subject. Moreover, the tests are time tested and require the quickest of solutions. It would seem likely that the assessment system encourages surface approaches to learning. There are several possible alternatives:

- *Adoption of more assignments* Opportunity students were given these every week but the regular students only fortnightly (Chapter 3). As assignments were found to contribute more to learning than tests, shifting more of the assessment to assignment could be trialled and evaluated.
- As suggested for the Enabling Mathematics subject, there is a need for students to completely master the skills when they complete MATH141. Partial mastery is not an option. Adopting an approach like the Keller (1974) plan, where students are required to be competent in the requisite skills in order to pass, is also worthy of trial.

- Given the emphasis on social discourse in learning in constructivist philosophy, and the success of programs such as the Peer Assisted Study Sessions (PASS), the idea of project work to encourage the sharing of ideas and collaboration may also be worthy of trial.

Within the existing system of assessment there are also refinements that may be more acceptable, though possibly of less dramatic effect, than a fundamental change to the entire assessment system.

- In response to student requests it may be preferable to allocate a greater percentage for assignments and to change the marking system. Rather than tutors marking assignments with an overall satisfactory 'S' or unsatisfactory 'U' for attempting questions, a score or mark of, say 20, could be used to reward correct steps or partially correct solutions, thus providing feedback.
- It is very important that tutors provide feedback to students and the literature supports this notion. Notes and hints can be written at various stages of their worked solutions and they can be advised to see attached fully worked solutions.

9.4.5 Nature of Video Resources

For the most part, students appeared satisfied with the resources they had been provided, but indeed they have more progress to make. Evaluations suggested that there were gains in concept development in addition to skills. The request for additional resources decreased dramatically in 2007 compared to 2006 when a partial set of resources was available. Only a small proportion of students requested development in the area of theory refreshers and rules, even though these were lacking for the majority of topics.

It is quite feasible that the video resources have met students' needs to survive and pass the subject. Davis and McGowen (2005) characterised the fragility of students' learning when students did not recognise one or another form of paired questions reflecting different perspectives of the same topics. It may be that only a few students recognised the need to deepen their learning. There was some evidence provided by students being unable to answer both questions on a given topic in the skills test. Indeed, Niss (1999) in discussing the didactics of mathematics wrote:

> … it is a non-trivial matter of teaching and learning to establish mathematical concepts with students so as to be both sufficiently general and sufficiently concrete. Research further suggests … that for this to happen, several different *representations* (e.g. numerical, verbal, symbolic, graphical, diagrammatical) of concepts and phenomena are essential (p. 17).

Similarly, Engelbrecht, Harding and Potgieter (2005) successfully combined skill acquisition and conceptual development in their program by a reform approach to teaching calculus. They provided an emphasis on understanding problems, with concepts also being introduced in several ways: ‘verbally, numerically, algebraically and visually’ (p. 710). The selection of examples involved the working of ‘all rules’ that applied to the topic, for example, all instances of working with indices. Examples with different levels of difficulty or complexity in terms of the number of steps were also developed. However, in keeping with the context of MATH141 and the orientation of rapidly executing a skill, multiple representations were not considered. The time allowed in the Basic Skills Tests only permitted the most rapid execution of skills. To deepen students’ learning and understanding, development of the resources should extend to solutions being provided using different representations. This should be accommodated by a change in assessment strategies.

From the evaluations, and to encompass alternative constructivist approaches, modification to the video resources should entail:

- extension of the ‘theory refreshers’ by embedding animations, such as those provided by Talman (2007) or scripts such as Bolands (2002) so that students can visualise and experience mathematics rather than only being instructed in the process,
- extension in the nature of questions posed so that students learn to apply mathematics in discipline-specific contexts,
- ensure that all rules and definitions and special cases in mathematics, such as division by zero, associated with a topic are covered and

- provision of examples and solutions involving different representations (algebraic, visual, verbal and algebraic).

9.4.6 Embedding the Video Resources

Providing supplementary learning resources such as video resources is useful for students' learning and understanding if the following actions taken place:

- References to the video resources should be made throughout, as some students did not know of the existence of video resources!! All other lecturers and tutors should be notified of the use of the video resources at the start of the session, not towards the end. Two lecturers teaching MATH141 indicated that they did not refer students to the video resources to support learning. This also suggests that there should be better communication between lecturers, so that developments to support learning by one lecturer is not thwarted by the actions of the others.
- It is not enough to upload learning resources onto WebCT or Blackboard Vista without advertising their availability. Students need to be educated to use the resources.
- It is necessary to provide a copy of the questions for which there are video solutions and to advise lecturers to use some of them in their lecturing.
- The use of video solutions as an example during teaching should be recommended. These can be left at some stage and students encouraged to see the rest of the worked solutions via video. This is a way to motivate students to see not just that example but maybe to try extra ones.
- Tutors should be provided with a copy of questions for which there are video solutions and advised to use similar questions in their assignments, so that the learning resources are aligned with assessment. Students should be advised that if they have had any problems with the questions in the assignments, there are similar questions in the video resources which might help.
- Students should be informed about the existence of video resources via *Information Sheet for Mathematics 1C Part 1- MATH141* and occasionally via email during session.

9.5 Conclusion

How best to provide video learning resources has not yet been resolved. It is clear from the work undertaken in this research, however, that the video resources are useful in assisting students to develop both their mathematical skills and concepts. It has been possible to improve learning outcomes. Further development of the resources may be needed in order to engage the 20% of students who still fail. This may be a simple extension of existing resources or it may involve developing more exciting ways to engage students, such as gaming, or providing relevance with mathematical applications specific to various disciplines. There is much scope to further improve the videos by introducing visualisations and alternative strategies for completing and asking questions. The interest shown by the academic community suggests that the work undertaken in this research project has the potential to capture the imagination of both staff and students. The framework that is developing in projects such as the Summertime Maths Project allows staff to conceptualise how their particular mathematical need for video resources can be met.

Similarly, there has been excitement in the prospect of sharing teaching and learning through the Access Grid. Students and staff have, for the most part, found this to be a valuable experience. There are pedagogical issues still to be resolved, such as ensuring that students at the distant university are not disadvantaged and that students are comfortable with communication. Similarly, lecturers need to be trained to use the facilities so that they do not simply replicate traditional lecturing modes but rather modify their teaching to benefit from the newer technologies. This too has been a successful endeavour, even though the technology is not yet robust or simple. Evaluation has led to a different combination of technologies that has provided an equivalent functionality with simpler demands on technical expertise. The concept of sharing subjects and students across the country is firmly established.

Technology rapidly becomes obsolete, but it also becomes more functional and easier to use. This suggests that there is indeed an enduring role for the use of technologies such those described in this thesis, in improving mathematical education.

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Appendix 1 Basic Skills Test 1. 2007

THE UNIVERSITY OF WOLLONGONG

SCHOOL OF MATHEMATICS AND APPLIED STATISTICS

MATH141: Mathematics 1C Part 1

Basic Skills Test

Time allowed : 35 minutes

Number of questions: 20 multiple choice

Attempt all questions.

CALCULATORS

ARE NOT PERMITTED.

Please Note: Examination Paper is printed on both sides.

1. $\dfrac{a^{-2}b \times ab^{-2}}{a^{-4}b^{3}}$ simplifies to

   (a) ab

   (b) $\dfrac{a^3}{b^4}$

   (c) $\dfrac{1}{a^3b^4}$

   (d) 1

   (e) $\dfrac{1}{ab}$

2. $\dfrac{x^2-4}{2x-4} \times \dfrac{2}{2+x}$ is equal to

   (a) 1

   (b) $\dfrac{2}{x-2}$

   (c) $\dfrac{x-2}{x+2}$

   (d) 0

   (e) 4

3. $\dfrac{3}{x-y} - \dfrac{2}{x+y}$ written as a single fraction is

   (a) $\dfrac{1}{x^2-y^2}$

   (b) $\dfrac{x}{x^2-y^2}$

   (c) $\dfrac{x+5y}{x^2-y^2}$

   (d) $\dfrac{y}{x^2-y^2}$

   (e) $\dfrac{3x-4y}{x^2-y^2}$

4. The expression $3m(m-1) - 2(m^2+2m+5)$ can be written more simply as

   (a) $-7m-10$

   (b) $5m^2+7m-10$

   (c) m^2+m-10

   (d) $m^2-7m-10$

   (e) none of these

5. $(x-1)^2-(2x)^2$ equals

   (a) $(-x-1)^2$

   (b) $(x+1)(1-3x)$

   (c) $-3x^2-1$

   (d) x^2-4x-1

   (e) None of the above

6. $\sqrt{a^2+b^2}$ is equal to

   (a) $a+b$

   (b) $\sqrt{a+b}$

   (c) $a-b$

   (d) none of the above

   (e) a^2+b^2

7. Given that $f(x)=x^2+3+\dfrac{1}{x^2}$ which of the following state ments is true?

   (a) $f(a)=f(-a)$

   (b) $f(a)=-f(a)$

   (c) $f(a)=f(a^2)$

   (d) $f(a)=0$

   (e) None of the above statements are true.

8. The values of x which satisfy the inequality $|3x-4|<2$ lie on the interval

   (a) $\left[\frac{2}{3},2\right]$

   (b) $\left(\frac{4}{3},2\right)$

   (c) $\left(-\frac{4}{3},2\right]$

   (d) $\left(\frac{2}{3},2\right)$

   (e) $\left[\frac{2}{3},2\right)$

9. Let $s = ut + \frac{1}{2}at^2$, where $u = 5$, $a = 6$ and $t = 2.4$ then the value of s is

   (a) 19.2

   (b) 29.28

   (c) 29

   (d) 31.68

   (e) 0

10. The domain of the function $f(x) = \frac{1}{\sqrt{1-x^2}}$ is the set of x such that

   (a) $|x| \leq 1$

   (b) $x \neq 1$

   (c) $|x| \geq 1$

   (d) x is all Real numbers

   (e) $|x| < 1$

11. The equation of the straight line perpendicular to $y = 2x + 3$ with y intercept 1 is

   (a) $y = -\frac{1}{2}x + 1$

   (b) $y = 1$

   (c) $y = 2x + 1$

   (d) $y = -\frac{1}{2}x - 1$

   (e) $y = 2x - 1$

12. The lines $y = 2x$ and $y = -3x + 1$ intersect at the point

   (a) $(1, 2)$

   (b) $(0, 0)$

   (c) $(-1, 4)$

   (d) $\left(\frac{1}{5}, \frac{2}{5}\right)$

   (e) do not intersect

13. Geometrically the equation $x^2 + 2x + y^2 = 0$ describes a

    (a) parabola

    (b) hyperbola

    (c) circle

    (d) straight line

    (e) ellipse

14. $\log_2 16$ is equal to

    (a) 2

    (b) 4

    (c) 16

    (d) 32

    (e) $\frac{1}{4}$

15. The expression $\log_a(xy^2) + \log_a(yz^2) - \log_a(xz^2)$ simplifies to

    (a) $\log_a(xy^2 + yz^2 - xz^2)$

    (b) $\dfrac{\log_a(xy^2 + yz^2)}{\log_a(xz^2)}$

    (c) $\log_a\left(\dfrac{xy^2 + yz^2}{xz^2}\right)$

    (d) 1

    (e) $3\log_a y$

16. The value of x that makes the equality $4^{x+1} = \frac{1}{8}$ true is

    (a) $x = -\frac{5}{2}$

    (b) all x

    (c) $x = -2$

    (d) $x = 2$

    (e) $x = \log_2 8$

17. The exact solutions to the equation $x^2 - 3x - 2 = 0$ are

(a) $x = \frac{3}{2} + \sqrt{17}$ or $x = \frac{3}{2} - \sqrt{17}$

(b) $x = \frac{3+\sqrt{17}}{2}$ or $\frac{3-\sqrt{17}}{2}$

(c) $x = 1$ or 2

(d) $x = \frac{3}{2}$ or $x = -\frac{3}{2}$

(e) no values of x exist

18. $\frac{2}{\sqrt{3}+1}$ is equal to

(a) $\sqrt{3+1}$

(b) $\sqrt{3} - 1$

(c) $\sqrt{3}$

(d) 2

(e) $\frac{\sqrt{3}-1}{2}$

19. Given x on the interval $0 \leq x \leq 2\pi$ such that $\sin x = \frac{1}{2}$, then x is equal to

(a) $\frac{\pi}{6}, \frac{7\pi}{6}$

(b) $\frac{5\pi}{6}, \frac{7\pi}{6}$

(c) $\frac{\pi}{6}, \frac{5\pi}{6}$

(d) $0, 2\pi$

(e) $\frac{\pi}{2}, \pi$

20. If $\sin\theta = \frac{3}{5}$ and $0 < \theta < \frac{\pi}{2}$ then $\tan\theta$ is equal to

(a) $\frac{3}{5}$

(b) $\frac{4}{5}$

(c) $\frac{5}{4}$

(d) none of the above

(e) $\frac{3}{4}$

MATH141 – Mathematics 1C, Part 1

Autumn Session 2007

Basic Skills Test B

*Student Name:*______________________________ *Student Number:*____________

Answer Sheet

Completely fill in the appropriate box for each question: ■

1. A B C D E

2. A B C D E

3. A B C D E

4. A B C D E

5. A B C D E

6. A B C D E

7. A B C D E

8. A B C D E

9. A B C D E

10. A B C D E

11. A B C D E

12. A B C D E

13. A B C D E

14. A B C D E

15. A B C D E

16. A B C D E

17. A B C D E

18. A B C D E

19. A B C D E

20. A B C D E

MATH141 – Mathematics 1C, Part 1

Autumn Session 2007

Basic Skills Test B

Student Name: Correct Answers Repeat Test ______ *Student Number:* 2004 ______

Answer Sheet

Completely fill in the appropriate box for each question: ■

1.	■	B	■	■	■
2.	A	■	■	■	■
3.	■	■	C	■	■
4.	■	■	■	D	■
5.	■	B	■	■	■
6.	■	■	■	D	■
7.	A	■	■	■	■
8.	■	■	■	D	■
9.	■	B	■	■	■
10.	■	■	■	■	E
11.	A	■	■	■	■
12.	■	■	■	D	■
13.	■	■	C	■	■
14.	■	B	■	■	■
15.	■	■	■	■	E
16.	A	■	■	■	■
17.	■	B	■	■	■
18.	■	B	■	■	■
19.	■	■	C	■	■
20.	■	■	■	■	E

Appendix 2 Basic Skills Test 2. 2007

THE UNIVERSITY OF WOLLONGONG

SCHOOL OF MATHEMATICS AND APPLIED STATISTICS

MATH141: Mathematics 1C Part 1

2007 Basic Skills Test

Time allowed : 35 minutes

Number of questions: 20 multiple choice

Attempt all questions.

There are two *optional* questions relating to your use of video resources.

SINGLE-LINE-DISPLAY CALCULATORS

WITHOUT ALPHANUMERIC KEYBOARDS ARE PERMITTED.

Please Note: Examination Paper is printed on both sides.

1. Simplify $2^a 4^b$

   (a) 8^{a+b}

   (b) 4^{2ab}

   (c) 4^{a+2b}

   (d) 2^{2ab}

   (e) 2^{a+2b}

2. $\dfrac{x}{x+1}$ equals

   (a) 1

   (b) $1 - \dfrac{1}{x+1}$

   (c) $\dfrac{1}{2}$

   (d) $\dfrac{1}{x}$

   (e) None of the above.

3. $\dfrac{x^n}{x^{n-1}}$ equals

   (a) $\dfrac{1}{x}$

   (b) x^{2n-1}

   (c) x

   (d) $\dfrac{n}{n-1}$

   (e) None of the above.

4. $\sqrt{a^2 - b^2}$ is equal to

   (a) $a - b$

   (b) $\sqrt{a-b}$

   (c) $a + b$

   (d) None of these

   (e) $a^2 - b^2$

5. Factorize $2x^2 - 3x - 2$.

   (a) $(x-2)\left(x+\frac{1}{2}\right)$

   (b) $(x-2)(2x+1)$

   (c) $(2x-1)(x+2)$

   (d) $-\frac{1}{2}, 2$

   (e) $(2x-1)(x-2)$

6. For what values of x is $|x-3| < 15$?

   (a) $x < -12, x > 18$

   (b) $x < 18$

   (c) $-12 < x < 18$

   (d) $x < 12, x > 18$

   (e) $x > 18$

7. If $f(z) = 2z + 1$ and $g(x) = \frac{1}{x}$ what is $g(f(a))$?

   (a) $\frac{2}{a} + 1$

   (b) $\frac{2}{x} + 1$

   (c) $\frac{1}{1+2a}$

   (d) $\frac{1}{2x+1}$

   (e) $\frac{1}{2a} + 1$

8. What is $\sin\frac{\pi}{2}$?

   (a) 0

   (b) 1

   (c) -1

   (d) $\frac{1}{2}$

   (e) $-\frac{1}{2}$

9. If $f(x) = 2^x$ what is 2^0?

   (a) 0

   (b) 1

   (c) infinity

   (d) -1

   (e) 2

10. Rearrange the following equation to find y: $\dfrac{1}{x} + x = \dfrac{1}{y}$.

   (a) $x + \dfrac{1}{x}$

   (b) $\dfrac{1+x}{x^2}$

   (c) $\dfrac{1+x^2}{x}$

   (d) $\dfrac{x}{1+x^2}$

   (e) $\dfrac{-x}{x^2-1}$

11. $2x + 2y = 9$ is the equation of

   (a) A circle, $r = 3$.

   (b) A circle, $r = 9$.

   (c) A straight line, $m = 2$.

   (d) A straight line, $c = 9$.

   (e) None of the above.

12. The equation of the line through $(-1, 2)$ and perpendicular to the line $y + 2x + 3 = 0$ is given by

   (a) $y = 2x - 3$

   (b) $x + 2y - 5 = 0$

   (c) $2y - x - 5 = 0$

   (d) $2x + y + 3 = 0$

   (e) $x + 2y + 3 = 0$

13. Let x, y, b and N be positive real numbers. Which of the following statements is **false**?

    (a) $\log_b (x+y) = \log_b x + \log_b y$

    (b) $N = b^x \Longleftrightarrow x = \log_b N$

    (c) $\log_b x^p = p \log_b x$

    (d) $\log_b 1 = 0$

    (e) $\log_b x^2 - \log_b y^2 = 2\log_b \left(\frac{x}{y}\right)$

14. If $\ln a = 2$ and $\ln b = 3$, evaluate $\ln \left(ab^2\right)$

    (a) -4

    (b) 8

    (c) -12

    (d) 11

    (e) 36

15. Suppose that $f(x)$ is a polynomial. Which of the following statements is true?

    (a) If $f(a) = 0$ then $x + a$ is a factor of $f(x)$

    (b) If $f(a) = 0$ then $x - a$ is a factor of $f(x)$

    (c) If $f(a) = 0$ then $a = 0$.

    (d) $f(a) = 0$, then $f(x)$ has no factors.

    (e) None of these statements are true.

16. $f(x) = 2x^3 - 3x^2 - kx + 20$ has $x - 5$ as a factor when

    (a) $k = 39$

    (b) $k = 0$

    (c) $k = 1$

    (d) $k = 5$

    (e) $k = -5$

17. Find the roots of the quadratic: $x^2 + 1 = 5x$

(a) $\dfrac{-5 \pm \sqrt{21}}{2}$

(b) $\dfrac{5 \pm \sqrt{29}}{2}$

(c) $\dfrac{5 \pm \sqrt{21}}{2}$

(d) $-\dfrac{1}{5}, 5$

(e) $\dfrac{-5 \pm \sqrt{29}}{2}$

18. $\left(\sqrt{8} - \sqrt{2}\right)^2$ equals

(a) 6.

(b) 2.

(c) $6 - 2\sqrt{2}$.

(d) $8 - 4\sqrt{2}$.

(e) None of these.

19. $\dfrac{3}{\sqrt{5} + 2}$ is equal to

(a) $3\left(\sqrt{5} - 2\right)$

(b) $\sqrt{5} - 2$

(c) $\sqrt{5}$

(d) $\dfrac{\sqrt{5} + 2}{3}$

(e) $\dfrac{\sqrt{5} - 2}{5}$

20. If $\sin x = \dfrac{4}{5}$ and $\dfrac{\pi}{2} \leq x \leq \pi$, then the exact value for $1 - \tan x$ is

(a) -52.13

(b) $\dfrac{7}{3}$

(c) 54.13

(d) $\dfrac{7}{4}$

(e) $-\dfrac{1}{3}$

The following two questions are optional.

21. How important are the video solutions for helping you to understand and learn the mathematics covered by the Mathematics Skills Review?

    (a) Not applicable — I rarely used the video resources.

    (b) Of little importance.

    (c) Moderately important.

    (d) Extremely important.

22. Indicate the usage that is closest to describing how you used the video resources.

    (a) I did not use them because I did not need them.

    (b) I would have like to use them but had difficulty accessing them.

    (c) I started to use them, but then decided I did not need to use them.

    (d) I used them for topics that I have difficulty with.

    (e) I used them for all topics that were available .

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MATH141 – Mathematics 1C, Part 1

Autumn Session 2007

Basic Skills Test D

*Student Name:*________________________________ *Student Number:*____________

Answer Sheet

Completely fill in the appropriate box for each question: ■

1. [A] [B] [C] [D] [E]
2. [A] [B] [C] [D] [E]
3. [A] [B] [C] [D] [E]
4. [A] [B] [C] [D] [E]
5. [A] [B] [C] [D] [E]
6. [A] [B] [C] [D] [E]
7. [A] [B] [C] [D] [E]
8. [A] [B] [C] [D] [E]
9. [A] [B] [C] [D] [E]
10. [A] [B] [C] [D] [E]
11. [A] [B] [C] [D] [E]
12. [A] [B] [C] [D] [E]
13. [A] [B] [C] [D] [E]
14. [A] [B] [C] [D] [E]
15. [A] [B] [C] [D] [E]
16. [A] [B] [C] [D] [E]
17. [A] [B] [C] [D] [E]
18. [A] [B] [C] [D] [E]
19. [A] [B] [C] [D] [E]
20. [A] [B] [C] [D] [E]

MATH141 – Mathematics 1C, Part 1

Autumn Session 2007

Basic Skills Test D

Student Name: Correct Answers Repeat Test ____________ *Student Number:* 2007 __________

Answer Sheet

Completely fill in the appropriate box for each question: ■

1.	■	■	■	■	E
2.	■	B	■	■	■
3.	■	■	C	■	■
4.	■	■	■	D	■
5.	■	B	■	■	■
6.	■	■	C	■	■
7.	■	■	C	■	■
8.	■	B	■	■	■
9.	■	B	■	■	■
10.	■	■	■	D	■
11.	■	■	■	■	E
12.	■	■	C	■	■
13.	A	■	■	■	■
14.	■	B	■	■	■
15.	■	B	■	■	■
16.	A	■	■	■	■
17.	■	■	C	■	■
18.	■	B	■	■	■
19.	A	■	■	■	■
20.	■	B	■	■	■

Appendix 3 Mid-Session Test. 2007

THE UNIVERSITY OF WOLLONGONG
SCHOOL OF MATHEMATICS AND APPLIED STATISTICS

MATH141: Mathematics 1C Part 1

Autumn Session 2007

2007 Mid-Session Test

Student Name:______________________________ *Student Number*:____________

Tutorial Group:_____ *Tutorial Day & Time*: ________________ *Tutor*: ________________

Instructions

Time allowed: 90 minutes

Do NOT remove the Answer Sheet from the Question Section.

- *All questions are to be attempted:*
  25 Multiple choice questions (25 marks).
- *Working is to be done in the Question Section.*
- *Answers are to be marked on the page entitled Answer Sheet by completely shading the box with the letter of your chosen response.*
- *Answers should also be marked on the Question Section.*
- *Write your name on both the Question Section and the Answer Sheet.*
- *At the end of the test return the complete test paper, including the Answer Sheet.*

Calculators are permitted.

A one-page, A4-sized, double-sided summary sheet is permitted.

This test paper is NOT to leave this room.

1. Let $A = (a_{ij}) = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix}$ and let δ_{ij} be the Kronecker delta. Then the expression $\displaystyle\sum_{k=1}^{3}\sum_{i=1}^{3} a_{ki}\delta_{3k}\delta_{i2}$ is equal to

   (a) 0.

   (b) 6.

   (c) 8.

   (d) 12.

   (e) 45.

2. Given that $A = \begin{pmatrix} 3 & 6 \\ -4 & -8 \end{pmatrix}$, and $B^T = \begin{pmatrix} -10 & 5 \\ -4 & 2 \\ 2 & 1 \end{pmatrix}$, the matrix product AB is

   (a) undefined.

   (b) $Z_{2\times 3}$.

   (c) $Z_{3\times 2}$.

   (d) $\begin{pmatrix} 0 & 0 & 12 \\ 0 & 0 & -16 \end{pmatrix}$.

   (e) $\begin{pmatrix} -50 & -100 \\ -20 & -40 \\ 2 & 4 \end{pmatrix}$.

3. Of the following, the matrix that is **NOT** an elementary matrix is

   (a) $\begin{pmatrix} 1 & 0 & 0 \\ 0 & \frac{1}{2} & 0 \\ 0 & 0 & 1 \end{pmatrix}$.

   (b) $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 1 \end{pmatrix}$.

   (c) $\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$.

   (d) $\begin{pmatrix} 1 & 0 & -2 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$.

   (e) $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & \frac{1}{2} \\ 0 & 1 & 0 \end{pmatrix}$.

4. Given the matrix $A = \begin{pmatrix} 1 & -1 & 2 & 0 \\ -1 & 1 & -1 & -1 \\ 2 & -2 & 7 & -2 \\ -2 & 2 & -5 & 3 \end{pmatrix}$, the reduced echelon form for A is given by

(a) $\begin{pmatrix} 1 & -1 & 2 & 0 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 2 \end{pmatrix}$.

(b) $\begin{pmatrix} 1 & -1 & 2 & 0 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$.

(c) $\begin{pmatrix} 1 & -1 & 2 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$.

(d) $\begin{pmatrix} 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$.

(e) $\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$.

5. For a homogeneous system of equations with matrix of coefficients A, if the rank of A is less than the number of rows in A, then the system has

(a) a unique solution which is the trivial solution.

(b) a unique solution which is non-trivial.

(c) at least one solution and we cannot determine if it has more solutions.

(d) an infinite number of solutions.

(e) no solution.

6. Given that $A = \begin{pmatrix} 1 & 2 & -4 \\ -1 & 1 & 1 \\ 1 & 5 & -7 \end{pmatrix}$, $\underset{\sim}{b} = \begin{pmatrix} 1 \\ -1 \\ 2 \end{pmatrix}$ and $\underset{\sim}{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$, the solution to the system of equations $A\underset{\sim}{x} = \underset{\sim}{b}$ is

(a) $\begin{pmatrix} 3 \\ -1 \\ 1 \end{pmatrix}$.

(b) $\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix} t$.

(c) $\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} t$.

(d) existent but none of these.

(e) non-existent.

7. The values of k for which the system given by

$$\begin{array}{ccccc} 3x & + & 2y & = & 11 \\ 6x & + & ky & = & 21 \end{array}$$

has (i) a unique solution (ii) no solutions (iii) infinitely many solutions are

(a) (i) $k = 4$; (ii) no k; (iii) $k \neq 4$.

(b) (i) no k; (ii) $k \neq 4$; (iii) $k = 4$.

(c) (i) all k; (ii) no k; (iii) no k.

(d) (i) $k \neq 4$; (ii) $k = 4$; (iii) no k.

(e) none of these.

8. Given that $A = \begin{pmatrix} 1 & 2 & 0 \\ -1 & 0 & 1 \\ 0 & 2 & 0 \end{pmatrix}$, $\underset{\sim}{b} = \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ and $\underset{\sim}{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$, then

(a) $A^{-1} = \begin{pmatrix} 1 & 0 & -1 \\ 0 & 0 & \frac{1}{2} \\ 1 & 1 & -1 \end{pmatrix}$ and the system $A\underset{\sim}{x} = \underset{\sim}{b}$ has a unique solution.

(b) $A^{-1} = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 0 & \frac{1}{2} \\ 1 & 1 & -1 \end{pmatrix}$ and the system $A\underset{\sim}{x} = \underset{\sim}{b}$ has an infinite solution.

(c) $A^{-1} = \begin{pmatrix} 1 & 0 & -1 \\ 1 & 1 & -1 \\ 0 & 0 & \frac{1}{2} \end{pmatrix}$ and the system $A\underset{\sim}{x} = \underset{\sim}{b}$ has no solution.

(d) A^{-1} does not exist and the system $A\underset{\sim}{x} = \underset{\sim}{b}$ has an infinite solution.

(e) A^{-1} does not exist and the system $A\underset{\sim}{x} = \underset{\sim}{b}$ has no solution.

9. The determinant of the matrix $\begin{pmatrix} 1 & 0 & 2 & -3 \\ 0 & 0 & 5 & 0 \\ -2 & 6 & 1 & 9 \\ 0 & 3 & -8 & 1 \end{pmatrix}$ is equal to

   (a) 15.
   (b) -15.
   (c) 0.
   (d) -30.
   (e) 30.

10. The determinant of the matrix $\begin{pmatrix} 1 & a & a^2 \\ 1 & b & b^2 \\ 1 & c & c^2 \end{pmatrix}$ is

   (a) $(a-b)(b-c)(a-c)$.
   (b) $-(a-b)(b-c)(a-c)$.
   (c) 0.
   (d) 1.
   (e) None of the above.

11. The expression $\sum_{i=1}^{3}\sum_{j=1}^{3}(i+2j)$ is equal to

   (a) 36.
   (b) 18.
   (c) 54.
   (d) 6.
   (e) None of the above.

12. The value of $\lim_{x\to 1}\dfrac{x^4-1}{x-1}$ is

   (a) 0.
   (b) 1.
   (c) 2.
   (d) 4.
   (e) non-existent.

13. If $y = \dfrac{2}{x^3}$ then $\dfrac{\mathrm{d}y}{\mathrm{d}x}$ is given by

   (a) $\dfrac{6}{x^2}$.

   (b) $-\dfrac{6}{x^4}$.

   (c) $2\ln\left|x^3\right|$.

   (d) $8x^2$.

   (e) $6x^{-4}$.

14. If $y = \sin 2x$ then $\dfrac{\mathrm{d}y}{\mathrm{d}x}$ is given by

   (a) $\cos 2x$.

   (b) $-\cos 2x$.

   (c) $-2\cos 2x$.

   (d) $2\cos 2x$.

   (e) $2\sin 2x$.

15. If $f(x) = \dfrac{1}{(1-3x)^2}$ then $\dfrac{\mathrm{d}f(x)}{\mathrm{d}x}$ is given by

   (a) $-\dfrac{1}{2}(1-3x)^{-3}$.

   (b) $-\dfrac{3}{(1-3x)^3}$.

   (c) $\dfrac{1}{2(1-3x)}$.

   (d) $\dfrac{6}{(1-3x)^3}$.

   (e) $-\dfrac{3}{2(1-3x)}$.

16. If $y(t) = e^t(\cos t + \sin t)$ then $\dfrac{\mathrm{d}y}{\mathrm{d}t}$ is given by

   (a) $2e^t \sin t$.

   (b) $2e^t \cos t$.

   (c) $te^t(\cos t + \sin t)$.

   (d) $e^t(-\sin t + \cos t)$.

   (e) $e^t(\sin t - \cos t)$.

17. By rearranging the equation $\sqrt{\frac{1}{y}-\frac{1}{x}}=\frac{1}{4}$, y can be found to be

(a) $16+x$.

(b) $16-x$.

(c) $\left(\frac{1}{16}+\frac{1}{x}\right)$.

(d) $\frac{16x}{x+16}$.

(e) $4+x$.

18. If $|x+2|>1$ then

(a) $x>-1$, or $x<-3$.

(b) $-1<x<3$.

(c) $-3<x<-1$.

(d) $x<-1$.

(e) $x>3$.

19. If $f\left(z\right)=2z+1$ and $g\left(x\right)=\frac{1}{x}$ then $f\left(g\left(a\right)\right)$ is given by

(a) $\frac{2}{a}+1$.

(b) $\frac{2}{x}+1$.

(c) $\frac{1}{2a+1}$.

(d) $\frac{1}{2x+1}$.

(e) $\frac{1}{2a}+1$.

20. If $\ln x=7$ and $\ln y=2$, then the value of $\ln\left(\frac{x^2}{y}\right)$ is

(a) 12.

(b) $\ln\left(24\frac{1}{2}\right)$.

(c) 47.

(d) $48\frac{1}{2}$.

(e) 10.

21. The expression $\sin(3A - B) + \sin(A + 3B)$ is equal to

(a) $\sin(4A + 2B)$.

(b) $2\cos(A + B)\sin\left(\dfrac{A - B}{2}\right)$.

(c) $2\sin(2A + B)\cos(A - 2B)$.

(d) $2\sin(A + B)\cos(A - 2B)$.

(e) None of the above.

22. If $2^x = \dfrac{5}{2}$ and $2^y = 3$, then 2^{x+y} is equal to

(a) 6.5.

(b) 7.5.

(c) 5.5.

(d) 1.5.

(e) $2^{5.5}$.

23. If $y = \dfrac{\sin x}{x}$ then $\dfrac{\mathrm{d}y}{\mathrm{d}x}$ is given by

(a) $\dfrac{\cos x}{x}$.

(b) $\dfrac{x\cos x - \sin x}{x^2}$.

(c) $\dfrac{-x\cos x - \sin x}{x^2}$.

(d) $\dfrac{x\cos x + \sin x}{x^2}$.

(e) $\cos x$.

24. Which ones of the following equalities holds?

 (a) $\dfrac{1+\sin x}{\cos x} = \dfrac{\cos x}{1+\sin x}$.

 (b) $(\sin x - \cos x)^2 = 1 + \sin 2x$.

 (c) $\dfrac{\cos 2x}{\cos x + \sin x} = \cos x + \sin x$.

 (d) $\dfrac{\sin x}{1+\cos x} + \dfrac{1+\cos x}{\sin x} = 2 \operatorname{cosec} x$.

 (e) None of the above.

25. The largest possible domain for the function $f(x) = \sqrt{\ln x - 1}$ (where $f(x)$ is real-valued) is

 (a) $[e, \infty)$.

 (b) $\mathbb{R}$.

 (c) $\mathbb{R}^+$.

 (d) $[1, \infty)$.

 (e) unable to be determined.

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MATH141: Mathematics 1C Part 1

Autumn Session 2007

2007 Mid-Session Test A

Student Name:____________________________ *Student Number*:____________

Answer Sheet

Completely fill in the appropriate box for each question: ■

1. A B C D E
2. A B C D E
3. A B C D E
4. A B C D E
5. A B C D E
6. A B C D E
7. A B C D E
8. A B C D E
9. A B C D E
10. A B C D E
11. A B C D E
12. A B C D E
13. A B C D E
14. A B C D E
15. A B C D E
16. A B C D E
17. A B C D E
18. A B C D E
19. A B C D E
20. A B C D E
21. A B C D E
22. A B C D E
23. A B C D E
24. A B C D E
25. A B C D E

MATH141: Mathematics 1C Part 1

Autumn Session 2007

2007 Mid-Session Test A

Student Name: Correct Answers *Student Number*: ____________

Answer Sheet

Completely fill in the appropriate box for each question: ■

1.	■	■	C	■	■
2.	■	■	■	D	■
3.	■	■	■	■	E
4.	■	■	■	D	■
5.	■	■	■	D	■
6.	■	■	■	■	E
7.	■	■	■	D	■
8.	A	■	■	■	■
9.	A	■	■	■	■
10.	■	B	■	■	■
11.	■	■	C	■	■
12.	■	■	■	D	■
13.	■	B	■	■	■
14.	■	■	■	D	■
15.	■	■	■	D	■
16.	■	B	■	■	■
17.	■	■	■	D	■
18.	A	■	■	■	■
19.	A	■	■	■	■
20.	A	■	■	■	■
21.	■	■	C	■	■
22.	■	B	■	■	■
23.	■	B	■	■	■
24.	■	■	■	D	■
25.	A	■	■	■	■

Appendix 4 Final Exam. 2007

Family Name	________________
First Name	________________
Student Number	________________
Table Number	________________

University of Wollongong

School of Mathematics and Applied Statistics

MATH 141 — MATHEMATICS 1C, PART 1

Autumn Session Examination 2007

Time Allowed: 3 hours and 15 minutes

Number of Questions: 4.

Directions to Candidates

1. Each question is to be attempted.
2. The four questions are of equal value (individual parts within a question may not be of equal value).
3. The examination paper is printed on both sides.
4. Four solution books are provided. The solution to each question is to be submitted in its own separate, clearly labelled, solution book.
5. WORKING (including all necessary reasoning) is to be shown for all solutions.
6. All notation is as used in lectures.

Examination Materials/Aids Allowed

Non-alphanumeric, non-programmable, calculators are permitted.
A one-page, double-sided, A4 size summary sheet is permitted.

Examination Materials/Aids to be supplied

A Table of Integrals is attached.

A sheet with two polar grids is attached.

This examination paper must NOT be removed from the examination room.

Question 1 (*Use a separate book for your answers to Question 1. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) Let $A = \begin{pmatrix} 0 & 1 & 1 \\ 1 & -1 & 1 \\ 2 & 3 & 7 \end{pmatrix}$, $\underline{x} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$ and $\underline{b} = \begin{pmatrix} -1 \\ 0 \\ -5 \end{pmatrix}$.

(i) Write down A^T, the transpose of the matrix A.

(ii) Compute $\det A$, the determinant of the matrix A.

(iii) Using no more than three elementary row operations, reduce the augmented matrix $(A \mid \underline{b})$ to echelon form, $\left(A^E \mid \underline{b}^E\right)$.

(iv) Hence, or otherwise, find the solution of the matrix equation $A\underline{x} = \underline{b}$.

(v) Is there a solution to $A\underline{x} = \underline{b}$ with $y = 1$? If so, write down the corresponding $\underline{x}$. If not, explain why not.

(vi) Write down the elementary matrices E_1, E_2, E_3 corresponding to the row operations performed in (iv).

(vii) Write down the simplified product of matrices EA, where $E = E_3E_2E_1$.

(b) Let

$$B = \begin{pmatrix} 1 & 2 \\ 2 & -2 \end{pmatrix}.$$

(i) Write down the polynomial equation satisfied by the eigenvalues λ of B.

(ii) Hence, or otherwise, find the eigenvalues of B.

(iii) Find an eigenvector corresponding to each eigenvalue of B.

(iv) Using matrix multiplication and addition, verify that

$$B^2 + B - 6I = Z,$$

where I is the 2×2 identity matrix and Z is the 2×2 zero matrix.

(v) Multiply the equation in (iv) by B^{-1} and rearrange, to obtain down a formula for B^{-1}, *in terms of* B.

(vi) Using the formula from (b) (v), or otherwise, compute B^{-1} in the form

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix}.$$

(vii) Verify that $BB^{-1} = I$.

(viii) Using the result of (b) (vi), or otherwise, solve the following systems of linear equations:

$$(I) \quad \begin{aligned} x + 2y &= 0 \\ 2x - 2y &= 0 \end{aligned}$$

$$(II) \quad \begin{aligned} x + 2y &= 3 \\ 2x - 2y &= -6 \end{aligned}$$

Question 2 (*Use a separate book for your answers to Question 2. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) Simplify $\sqrt{27}\sqrt{3}$

(b) Factorise the following quadratic equation

$$y\left(x\right)=2x^{2}+x-1.$$

(c) Sketch the graph of the function

$$xy=4.$$

(d) Express the following as simply as possible

$$6x^{3}y^{-2}\times\frac{1}{24}x^{-5}y^{4}.$$

(e) $n!$ is the number of ways in which it is possible to arrange n objects.

Let's suppose that it takes fifteen seconds to go from one arrangement to another. Then it takes $2!\times 15=30$ seconds to view all the arrangements of two objects and $3!\times 15=90$, seconds to view all the arrangements of three objects.

How long does it take to take to view all the arrangements of ten objects? (convert your answer to days).

(f) Given that $h(0.5)=0$ determine the zeros of the function

$$h\left(x\right)=2x^{3}-3x^{2}+0.5.$$

(g) (i) Evaluate the following limit if it exists

$$\lim_{x\to 0}\left(x-2\right)\left(x-3\right).$$

(ii) Give an example of functions f and g such that the following hold.

$$\lim_{x\to 0}f\left(x\right)=0,\qquad \lim_{x\to 0}g\left(x\right)=0,\qquad \text{and}\qquad \lim_{x\to 0}\frac{f\left(x\right)}{g\left(x\right)}\qquad \text{does not exist.}$$

(iii) Evaluate the following limit if it exists

$$\lim_{x\to -\infty}\frac{2x^{2}+3x+4}{5x^{2}+4x+3}.$$

(h) (i) If $\sinh x=4$, write down the *exact* value of $\cosh x$.

(ii) Does the function $f\left(x\right)=x^{2}-2x-3$ defined on the domain $\mathbb{R}$ have an inverse? If so, find the inverse function together with its domain, range and graph. If not, *justify* your answer.

(iii) Differentiate the function $y=\cos^{-1}\left(x^{2}+x\right)$.

Question 3 (*Use a separate book for your answers to Question 3. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) Let $\vec{a} = (-1, 2, 2)$, $\vec{b} = (-3, 0, 4)$ and $\vec{c} = (4, 1, 3)$.

(i) Find the unit vector of $\vec{a}$ and $3\vec{a}$.

(ii) Determine if vectors $\vec{b}$ and $\vec{c}$ are perpendicular.

(iii) Find the projection of $\vec{a}$ on $\vec{b}$ and that of $\vec{a}$ on $-2\vec{b}$.

(b) (i) Find the vector parametric equation of the line $\mathcal{L}_1$ passing through the points $P(3, -1, 0)$ and $Q(1, -2, 1)$.

(ii) Given the line $\mathcal{L}$ defined by

$$\mathcal{L}: \quad \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 2 \\ 1 \end{pmatrix} + \begin{pmatrix} -1 \\ 2 \\ 1 \end{pmatrix} s,$$

determine if the lines $\mathcal{L}$ and $\mathcal{L}_1$ intersect, are parallel or are skew, where $\mathcal{L}_1$ is the line found in (b)(i).

(iii) For the line $\mathcal{L}$ given in part (b)(ii), find the distance between $\mathcal{L}$ and the point $R(2, 1, 1)$.

(c) (i) Consider the three points $A(1, 1, 1)$, $B(2, -1, -2)$ and $C(3, -1, 2)$. Find $\overrightarrow{AB}$, $\overrightarrow{AC}$ and $\overrightarrow{AB} \times \overrightarrow{AC}$.

(ii) Using (c)(i), represent the plane $\mathcal{P}_1$ that passes through the points $A(1, 1, 1)$, $B(2, -1, -2)$ and $C(3, -1, 2)$ in vector parametric form.

(iii) Using (c)(i), show that the linear form of the equation representing $\mathcal{P}_1$, found in part (c)(ii), is given by

$$8x + 7y - 2z = 13.$$

Question 4 (*Use a separate book for your answers to Question 4. Failing to use a separate answer book may mean that your answer is not marked.*)

(a) (i) Differentiate the function $y = \frac{1}{5}\left(7x^3 - \frac{1}{2}x^2 + 2x - 3\right)$ with respect to x

(ii) Differentiate the function $y = x \tan x$ with respect to x.

(iii) By writing $\operatorname{sech} x$ as $(\cosh x)^{-1}$ show that

$$\frac{\mathrm{d}}{\mathrm{d}x}(\operatorname{sech} x) = -\operatorname{sech} x \tanh x.$$

(iv) Differentiate the function $y = \cos(\sin x)$ with respect to x.

(v) Differentiate the function $y = x^{\sin x}$.

(b) Find $\frac{\mathrm{d}^2 y}{\mathrm{d}x^2}$ if $\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{x + \sin x}{2y - \sin y}$.

(c) A curve is defined by the parametric equation $x(t) = t\cos(t)$ and $y(t) = \sin(t)$. Calculate $\frac{\mathrm{d}y}{\mathrm{d}x}$ and $\frac{\mathrm{d}^2 y}{\mathrm{d}x^2}$.

(d) (i) Find the value(s) of r when $\theta = \frac{6.5\pi}{12}$ if $r = 5\cos 3\theta$.

(ii) Using the polar graph paper provided at the end of the exam paper sketch the function $r = 5\cos 3\theta$, $0 \le \theta \le 2\pi$. The following set of values may be useful

θ	$\frac{0\pi}{12}$	$\frac{1\pi}{12}$	$\frac{2\pi}{12}$	$\frac{3\pi}{12}$	$\frac{4\pi}{12}$	$\frac{5\pi}{12}$	$\frac{6\pi}{12}$	$\frac{7\pi}{12}$	$\frac{8\pi}{12}$	$\frac{9\pi}{12}$	$\frac{10\pi}{12}$	$\frac{11\pi}{12}$	$\frac{12\pi}{12}$	$\frac{13\pi}{12}$
r	5	3.5	0	-3.5	-5	-3.5	0	3.5	5	3.5	0	-3.5	-5	-3.5
θ	$\frac{14\pi}{12}$	$\frac{15\pi}{12}$	$\frac{16\pi}{12}$	$\frac{17\pi}{12}$	$\frac{18\pi}{12}$	$\frac{19\pi}{12}$	$\frac{20\pi}{12}$	$\frac{21\pi}{12}$	$\frac{22\pi}{12}$	$\frac{23\pi}{12}$	$\frac{24\pi}{12}$			
r	0	3.5	5	3.5	0	-3.5	-5	-3.5	0	3.5	5			

You should also use your answer to (d)(i).

You should detach the polar graph paper from the exam paper and put it inside your answer book. Failure to do this may mean that your answer is not marked.

(e) Evaluate the following integrals.

(i) $\int_2^3 3e^{2x}\,\mathrm{d}x$

(ii) $\int e^{18x} \sin 4x\,\mathrm{d}x$

(iii) $\int \frac{\mathrm{d}x}{x\sqrt{19x+6}}$

(iv) $\int_2^4 (2x-3)^5\,\mathrm{d}x$

(v) $\frac{\mathrm{d}}{\mathrm{d}x}\int_{75}^{\tan x} t^2 \sin t\,\mathrm{d}t$

Appendix 10

Observation/Interview Protocol
Use of Video Resources in 2006

The purpose of this survey is to evaluate the effectiveness of the video and eBeam solutions developed for you in MATH141. Students will be asked to answer questions. The following are samples as questioning will be directed by student responses.

1. Did you use the **video solutions** or the **eBeam solutions** to correct your mistakes and/or improve your understanding and learning of the mathematics covered in the skills test?
   a. No
   b. Once or twice
   c. Frequently

2. How was the picture quality of the **video solutions**?
   a. Too poor to use
   b. Poor
   c. Good
   d. More than adequate

3. How was the picture quality of the **eBeam solutions**?
   a. Too poor to use
   b. Poor
   c. Good
   d. More than adequate

4. How was the voice quality of the **video solutions** or the **eBeam solutions**?
   a. Too poor to use
   b. Poor
   c. Good
   d. More than adequate

5. For the **video solutions** or the **eBeam solutions** did you prefer the simple voice solution or the detailed voice solution?

…………………………………………………………………………………………….

6. How important are **detailed** voice solutions for helping you to understand and learn mathematics covered by the skills test?

…………………………………………………………………………………………….

7. Do you prefer to have voice for all the solution or just for main and central concepts?

…………………………………………………………………………………………….

8. In the eBeam or video solutions do you prefer **simple plus explanation** voice or **detailed** voice?

…………………………………………………………………………………………….

9. Does the on-screen hand in some of the **video solutions** help you to understand and learn mathematics?
   a. No
   b. I didn't notice it
   c. Yes

10. How did you find the use of the **video solutions** or the **eBeam solutions**?
    a. It was time consuming for me to use them.
    b. I found it difficult to use them.
    c. I solved questions well when I use them

11. I believe that by using the **video solutions** or the **eBeam solutions** in this subject I could increase my capacity to understand and learn more.
    a. Not at all.
    b. I have tried and feel I have made no progress.
    c. I have tried and feel I have made limited progress.
    d. I have tried and feel I have more confident to deal with mathematics question.

12. How best can the **video solutions** resources be improved to help your understanding and learning of mathematics?

………………………………………………………………………………………….

13. How best can the **eBeam solutions** resources be improved to help your understanding and learning of mathematics?

………………………………………………………………………………………….

14. Do you have any other suggestions for the improvement of this subject?

………………………………………………………………………………………….

15. Is your goal in learning mathematics to solve problems correctly or to understand the concepts?

………………………………………………………………………………………….

Appendix 11

Video Resources Survey after Mid-Session Test 2006

The purpose of this survey is to evaluate the effectiveness of the learning resources developed for you in MATH141. You would have accessed these learning resources, entitled: "Basic Skills Review" either via WebCT Vista or a CD-ROM given out in lectures. The first resource used a video camera and the voice of an unseen person explaining solutions to maths questions. The second was simply a worked/print solution (no video or voice). We wish to find out how these resources can be improved and if we should produce more of this type of resource.

1. On average how much time did you spend using the **video solutions** or the **worked solutions** either through the Website or from CD-ROM each week?
   a. 0-2 hours per week
   b. 3-5 hours per week
   c. 6-8 hours per week
   d. 9-11 hours per week
   e. 12 or more hours per week

2. How important are the **video solutions** for helping you to understand and learn the mathematics covered by the Basic Skills Review?
   a. Not applicable – I rarely used the video resources
   b. Of little importance
   c. Moderately important
   d. Extremely important

3. How important are the **worked solutions** for helping you to understand and learn the mathematics covered by the Basic Skills Review?
   a. Not applicable – I rarely used the worked resources
   b. Of little importance
   c. Moderately important
   d. Extremely important

4. Was the amount of voice enough for the **video solutions**?
   a. Too little
   b. Just right
   c. Too much

5. Do you like to listen to the voice for the **video solutions** when following the solutions?
   a. I prefer turn off the voice
   b. Just for some questions that I couldn't understand
   c. Yes

6. Does the on-screen hand in some of the **video solutions** help you to understand and learn mathematics better?
   a. No
   b. I didn't notice it
   c. Yes

7. How was picture quality of the **video solutions**?
   a. Too poor to use
   b. Poor
   c. Good
   d. More than adequate

8. Overall, did the **video solutions** help you understand and learn mathematics?
   a. Not at all
   b. Slightly
   c. Yes

9. Do you think the **video solutions** helped you to work independently of other students and tutors?
   a. No
   b. I did not use the video solutions
   c. A little bit more independently
   d. Yes

10. In the future, if a CD-ROM of the **video solutions** was available for all the topics, would you
    a. Not use it and only go to tutorials
    b. Use it in addition to going to tutorials
    c. Use it instead of tutorials
    d. Don't know

11. In the future, if a CD-ROM of the **worked solutions** was available for all the topics, would you
    a. Not use it and only go to tutorials
    b. Use it in addition to going to tutorials
    c. Use it instead of tutorials
    d. Don't know

12. How did you find the use of the **video solutions** or the **worked solutions**?
    a. It was time consuming for me to use them.
    b. I found it difficult to use them.
    c. I found it easy to use them.

13. I believe that by using the **video solutions** or the **worked solutions** in MATH141, I can now better understand and learn the course material.
    a. Did not use them
    b. False
    c. True
    d. Don't know

14. I believe that by using the **video solutions** or the **worked solutions** in MATH141, I can solve more mathematics problems than before.
    a. Did not use them
    b. False
    c. True
    d. Don't know

15. Would you like to have access to more **video solutions** or **worked solutions** for those parts of MATH141 presently not covered?
    a. No
    b. Yes
    c. Don't know

16. If you just access to the **video solutions** or the **worked solutions** which one do you prefer?
    a. Neither is required
    b. Video solutions
    c. Worked solutions
    d. Either is fine

17. To use **video solutions** I have been using
    a. PC (windows computer)
    b. Macintosh (Apple computer)
    c. Other

18. How have the **video solutions** or the **worked solutions** helped you to understand and learn mathematics?

……………………………………………………………………………………………….

19. How best can the **video solutions** resources be improved to help your understanding and learning of mathematics?

……………………………………………………………………………………………….

20. How best can the **worked solutions** resources be improved to help your understanding and learning of mathematics?

……………………………………………………………………………………………….

21. Which topics in MATH141 require more **video solutions** or **worked solutions** for practice?

……………………………………………………………………………………………….

22. How best can the MATH141 be improved?

……………………………………………………………………………………………….

23. What mark did you get out of 20 in Test in Week 1?

……………………………………………………………………………………………….

24. What mark did you get out of 20 in Test in Week 4?

……………………………………………………………………………………………….

25. What mark did you get out of 25 in Mid-Session Test?

……………………………………………………………………………………………….

26. Is English your first language?
    a. Yes
    b. No

27. Select your gender
    a. Female
    b. Male

Appendix 12

Change Evaluation
End of Autumn Session 2006

The primary purpose of this survey is to provide feedback that can assist in the development of MATH141, for future students. Some students attend lectures; others choose to use the materials on the course WebCT Page and some use both. Some students find some resources are more useful than others. The feedback of ALL students is valuable in this process.

Note: The findings of the research will be published in a thesis and journal articles.

Usefulness of Learning Resources So we know what learning resources to focus on – How useful are the existing resources in helping you understand in this subject	**Rarely used this resource**	**Little use**	**Moderately useful**	**Extremely useful**
1. …'s Lectures	1	2	3	4
2. …'s Lectures	1	2	3	4
3. …'s Lectures	1	2	3	4
4. …'s Lecture notes via WebCT	1	2	3	4
5. …'s Lecture notes via WebCT	1	2	3	4
6. …'s Lecture notes via WebCT	1	2	3	4
7. Fill in lecture notes for …'s topics	1	2	3	4
8. Textbook Mathematics 1C	1	2	3	4
9. WebCT Forum	1	2	3	4
10. Tutorial classes	1	2	3	4
11. Tutor in tutorial classes	1	2	3	4
12. Tutorial tasks	1	2	3	4
13. Tutorial solutions	1	2	3	4
14. Assignments	1	2	3	4
15. PASS program sessions	1	2	3	4
16. Basic Skills Tests	1	2	3	4
17. Mid-Session Test	1	2	3	4
18. Video Resources	1	2	3	4
19. Other work done in your own time	1	2	3	4

Identifying topics where you feel competent or not So we know what topics to focus on - How confident are you that you can solve problems involving	**Not at all**	**Might have a Little difficulty**	**Moderately confident**	**Could do this**
20. Fundamentals (Basic Skills)	1	2	3	4
21. Differentiation	1	2	3	4
22. Polar Coordinates	1	2	3	4
23. Integration	1	2	3	4
24. Matrices and Determinants	1	2	3	4
25. Vectors Geometry	1	2	3	4

26. Circle the topics where you need more video solutions:

Indices, Surds, Logarithms, Factorisation, Algebraic Fractions, Functions, Quadratic Equations, Geometry, Trigonometry, Limits, Elementary Differentiation, Hyperbolic functions, One-to-one and inverse functions, Inverse Trigonometric functions, Inverse Hyperbolic functions, Derivative of an inverse functions, Logarithmic Differentiation, Implicit Differentiation, Parametric Differentiation, Polar Coordinates, Polar Curves, Methods of Integration, Index and Sigma Notation, Application of Matrices to systems of Equation, Determinants, Eignvalue Problem, Dot product of Two Vectors, Cross Product of Two Vectors, Planes

27. Are there any mathematics topics that you would like to see in video?
…………………………………………………………………………………………………..

28. Do you consider that you have completed the lecture component by
    a. attending virtually all the lectures.
    b. attending virtually all the lectures and doing the exercises as they are required for assessment.
    c. attending virtually all lectures and doing the exercises in the textbooks.
    d. other

29. Including lectures and tutorials and work outside class, on average per week how much time did you spend for the first twelve weeks of session working on MATH141?
    a. 0-2 hours per week
    b. 3-5 hours per week
    c. 6-8 hours per week
    d. 9-11 hours per week
    e. 12-14 hours per week
    f. More than 14 hours per week

30. How many PASS program sessions did you attend?
    a. 0
    b. 1-3
    c. 4-6
    d. 7-9
    e. 10-13
    f. 14+

31. Given the work I have done and feedback obtained the grade I expect to get in this subject is:
    a. Fail (<45%)
    b. Pass conceded (45-49%)
    c. Pass (50-64%)
    d. Credit (65-74%)
    e. Distinction (75-84%)
    f. High distinction ($\geq$85%)

32. Compared to when I started MATH141, I now view mathematics
    a. as less relevant to my life and/or anticipated profession
    b. about the same relevance as when I commenced
    c. as more relevant to my life and/or anticipated profession

33. Do you consider that the assessment system is fair and that students basically earn the marks they get or is it rife with cheating or...?
……………………………………………………………………………………………………..

34. How best can the MATH141 be improved?
…………………………………………………………………………………………………….

35. What mark did you get out of 25 in Mid-Session Test?
…………………………………………………………………………………………………….

36. Is English your first language?
    a. Yes
    b. No

37. Select your gender
    a. Female
    b. Male

Appendix 13

Change Evaluation
End of Autumn Session 2007

The primary purpose of this survey is to provide feedback that can assist in the development of MATH141 for future students. Some students attend lectures; others choose to use the materials on the course eLearning Page and some use both. Some students find particular learning resources to be more useful than others. The way some subjects are structured may be important. Some types of assessment may be better for helping you learn and understand.

The feedback of ALL students is valuable in this process. You can let us know how to improve the subject so that you or future students can learn better.

Note: Summaries of this data may be used in research publications.

Usefulness of Learning Resources

We would like to know which learning resources to focus on – How useful are the existing resources in helping you understand this subject?	**Rarely used this resource**	**Little use**	**Moderately useful**	**Extremely useful**
1. …'s lectures	1	2	3	4
2. …'s lectures	1	2	3	4
3. …'s lectures	1	2	3	4
4. Lecture notes via eLearning	1	2	3	4
5. Fill in lecture notes	1	2	3	4
6. Textbook Mathematics 1C	1	2	3	4
7. eLearning Forum	1	2	3	4
8. Tutorial classes	1	2	3	4
9. Tutor in tutorial classes	1	2	3	4
10. Tutorial tasks	1	2	3	4
11. Tutorial solutions	1	2	3	4
12. Assignments	1	2	3	4
13. Quizzes	1	2	3	4
14. PASS program sessions	1	2	3	4
15. Basic Skills Tests	1	2	3	4
16. Mid-Session Test	1	2	3	4
17. Video Resources	1	2	3	4
18. Other work done in your own time	1	2	3	4

Identifying topics where you feel competent or not

We would like to know which topics to focus on - How confident are you that you can solve problems involving	**Not at all**	**Might have a Little difficulty**	**Moderately confident**	**Could do this**
19. Fundamentals (Basic Skills)	1	2	3	4
20. Differentiation	1	2	3	4
21. Polar Coordinates	1	2	3	4
22. Integration	1	2	3	4
23. Matrices and Determinants	1	2	3	4
24. Matrix notation, operations and row echelon form	1	2	3	4
25. Inverse, elementary matrices, determinants and eigenvalues/vectors	1	2	3	4
26. Vector Geometry	1	2	3	4
27. Vectors, dot product and cross product	1	2	3	4
28. Straight lines and planes in space	1	2	3	4

29. Are there any mathematics topics or other types of strategies that you would like to see in the videos? For instance: definition, mathematics rules, theory refreshers, etc.
…………………………………………………………………………………………

30. Do you consider that you have completed the lecture component by: (Please tick one)
    a. attending virtually all the lectures.
    b. attending virtually all the lectures and doing the exercises as they are required for assessment.
    c. attending virtually all lectures and doing the exercises in the textbooks.
    d. other

31. Including lectures and tutorials and work outside class, on average per week how much time did you spend for the first twelve weeks of session working on MATH141?
    a. 0-2 hours per week
    b. 3-5 hours per week
    c. 6-8 hours per week
    d. 9-11 hours per week
    e. 12-14 hours per week
    f. More than 14 hours per week

32. How many PASS program sessions did you attend?
    a. 0
    b. 1-3
    c. 4-6
    d. 7-9
    e. 10-13
    f. 14+

33. Given the work I have done and feedback obtained the grade I expect to get in this subject is:
    a. Fail (<45%)
    b. Pass conceded (45-49%)
    c. Pass (50-64%)
    d. Credit (65-74%)
    e. Distinction (75-84%)
    f. High distinction ($\geq$85%)

34. We have been trialling two approaches for developing video resources
    a. Video solutions with hand in the movie
    b. Video solutions with person in the movie

Which of these approaches do you prefer? Please explain.
……………………………………………………………………………………………

35. With worked/printed solutions in E-learning do you prefer
    a. **handwriting** print
    b. **typed** print

Why? Please explain.
……………………………………………………………………………………………

We would like to know how using the videos have helped you.
Identifying aspects of **understanding** and **problem solving** from using **videos**

Did you gain?	**No, did not gain this**	**Improved a little at this**	**Moderately better at this**	**Confident doing this**
36. Refresher of theory/rules/definitions	1	2	3	4
37. New way to start problems	1	2	3	4
38. How to complete the steps involved	1	2	3	4
39. Alternative approaches to completion	1	2	3	4
40. Alternative ways to layout work	1	2	3	4
41. Ways to self-check	1	2	3	4
42. Ways to distinguish what type of problem you were doing	1	2	3	4
43. Understanding of the concepts involved	1	2	3	4
44. Retention (easier remember concepts and procedures)	1	2	3	4
45. Skills in reading & writing mathematics	1	2	3	4
46. Motivation	1	2	3	4
47. More confidence	1	2	3	4
48. Other Please specify …..	1	2	3	4

49. How could the **video resources** be improved?
…………………………………………………………………………………………………

50. How best can the MATH141 be improved?
………………………………………………………………………………………

51. Is there anything that **we** could have done to help you make a **better or easier transition** from high school Maths to University Maths?
…………………………………………………………………………………………………

52. Is there anything that **you** could have done better to help you make a **better or easier transition** from high school Maths to university Maths?
…………………………………………………………………………………………………

53. What mark did you get out of 25 in Mid-Session Test?

54. Is English your first language?
    a. Yes
    b. No

55. Select your gender
    a. Female
    b. Male

Appendix 14

Observation/Interview Protocol
Use of Access Grid Nodes - Students

The purpose of this survey is to evaluate the effectiveness of the Access Grid which is used for teaching and learning mathematics. Students will be asked to answer questions. The following are samples as questioning will be directed by student responses.

1. Please clarify the name of subject and with which university/universities you shared the subject and how many students did the subject?

2. Do you think doing any subject via the Access Grid is better than normal/traditional learning and teaching? Why?

3. Did you have enough mathematics or statistics background to do the subject and to have a discussion about the subject with the others at both ends?

4. Were you comfortable with the discussion?

5. Could you read everything on the screen, e.g. mathematics or statistics formulae?

6. What's your experience of the learning/teaching via the Access Grid? What worked well and what did not?

7. Is there any difference to be at the receiving end or the other site? For example, for students at South Australia when lecturer is teaching from the University of Wollongong or there?

8. What kind of problems you had to do the subject?

9. Did you have to contact the lecturer?

10. Do you have any experiences with the technical part of the Access Grid? For example, difficulty with video, echo on audio, sharing data, connecting to a venue (such as firewall or multicast problems), not being able to see some participants (e.g. too small in the video window or not on camera).

11. Will it be good if the lecturer before their class to check their slides with both ends if it's ok or not?

12. Have you had any difficulty to share a data file e.g. Excel, SPSS…?

13. What's your idea about the synchronisation of the audio and video?

14. How you find to use of the Access Grid for doing a subject in terms of to be comfortable, interact with the instructor during lecture, to hear and see other audience members at other sites?

15. How easy was it for you to interact with other participants at your site and the other site?

16. How did that all your results quite different from what did you expected in terms of assessment?

17. What do you see as the main benefits of the Access Grid?

18. What most impressed you about the Access Grid technology in the session?

19. What least impressed you about the Access Grid technology in the session?

20. What’s your idea about the layout of seats which are set in the Access Grid? Are you comfortable when the lecturer teaches from here and look at the others on the other site?

21. How best can the Access Grid be improved to help your understanding and learning of mathematics or statistics?

22. Would you wish to control the technical aspects rather than have an operator?

23. Have you had subjects taught by video conference and how that compares would be useful?

24. Is there anything else that you would like to tell me about it?

Appendix 15

Observation/Interview Protocol
Use of Access Grid Nodes - Academic Staff

The purpose of this survey is to evaluate the effectiveness of the Access Grid which is used for teaching and learning mathematics and statistics at the University of Wollongong. Lecturers will be asked to answer questions. The following are samples as questioning will be directed by lecturer responses.

1. Would you please clarify the name of the subject/subjects that you've taught? With which university/universities you shared the subject? How many students did the subject?

2. Were the students at the university enrolled in the subject or did they simply attend some of the classes?

3. Do you think teaching any subjects via the Access Grid is *better than*, *equivalent to*, or *worse than* normal/traditional teaching? Why?

4. What is your experience of the teaching via the Access Grid? What worked well and what did not?

5. Do you use Mimio or document camera/viewer for teaching?

6. What is your experience with the Mimio or document camera/viewer, the resolution of it, moving off the writing (document camera), etc?

7. Were you comfortable with the Mimio or document camera/viewer to teach maths?

8. How does the preparation time and preparation style for the lecture in the Access Grid compare with normal/traditional lectures? Does he/she need to have a well-defined protocol on how the materials should be developed and distributed before, during and after the Access Grid session?

9. Do you have any idea about how to schedule the subject and course time length (number of lectures, lab hours, etc)?

10. Have you had discussion with students in both universities similar the normal classes? Were you comfortable to have discussion with both ends via the Access Grid?

11. Do you think is there any difference for students at the host university or at the distant university? For example, when you are teaching from here for students at the other end.

12. Do you think if students do a subject via the Access Grid they will get similar results to students completing it in a normal class?

13. In teaching a subject for 300 or 400 level, what's your opinion regarding how to deal with teaching the subject to the students at different universities having different backgrounds? Do you teach them some topics and refer to those topics which are prerequisites? What do you do for those subjects if you want to teach?

14. How you find to use of the Access Grid for teaching a subject in terms of to be comfortable, interact with other participants at your site and the other site during lecture, to hear and see other audience members at other sites?

15. How best can the Access Grid be improved to help your teaching of mathematics?

16. Do you have any idea about training staff re the Access Grid?

17. What kind of problems you had to teach the subject?

18. Do you have any experiences with the technical part of the Access Grid? For example, difficulty with video, echo on audio, sharing data, connecting to a venue (such as firewall or multicast problems), not being able to see some participants (e.g. too small in the video window or not on camera).

19. What’s your idea about the synchronisation of the audio and video?

20. Do you have any good backup strategies for when the Access Grid does not work?

21. What do you see as the main benefits of the Access Grid?

22. What most impressed you about the Access Grid technology in this session?

23. What least impressed you about the Access Grid technology in this session?

24. What’s your idea about the layout of seats which are set in the Access Grid? Are you comfortable when you teach from here and look at the others on the other site and here?

25. Would you wish to control the technical aspects rather than have an operator?

26. Have you had subjects taught by video conference and how that compares would be useful?

27. Is there anything else that you would like to tell me about it?