Online facilitated mathematics learning in vocational education

A design-based study

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Declaration

I, Syed Hasan Javed, declare that the PhD thesis entitled Online facilitated mathematics learning in vocational education – a design-based study is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature Date:

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Table of Contents

List of Tables

List of Figures

Abstract

The ubiquitousness of the Internet and communication technologies is having a significant influence on teaching and learning practices both in terms of what is learnt and how it is learnt. Mathematics teaching and learning in vocational education is also facing new challenges due to the enormous influence of new technologies on workplace practices. This study makes an attempt to design and implement a web-based learning environment to facilitate and enhance the teaching and learning of mathematics in a TAFE setting. The design and development of the web-based learning environment aimed at providing opportunities for more engaging and authentic learning activities and promoting the use of new learning technologies in mathematics teaching and learning. The study included a practical orientation of action to bring about a change in the practice of teaching of mathematics in vocational education.

Using a design-based research approach the study comprised two cycles. In the first cycle three mathematics teachers were involved in exploring Internet based mathematics resources and participated in the design of a website that consisted of twelve units of basic mathematical topics with facilities for both synchronous and asynchronous communication. This web-based learning environment known as Maths Concurrent Assistance (MCA) Online was then trialled with a number of mathematics teachers and students in mainly workshop mode. In the second cycle, the web-based learning environment was customised for a business mathematics module in a diploma course and trialled with a semester long course taught on campus in a blended learning format. Data obtained through classroom observation, WebCT logs, discussion board postings, test results and interviews were used to explore and analyse issues concerned with students' participation, access and use and the role of teacher in facilitating mathematics learning. The study also included a quasi-experimental research design to compare achievement and attitude of students who participated in this experiment with another group of students taught the same content by the same teacher in a traditional face-to-face mode with no Internet activities.

Results from the study indicate that students' successful participation in web-based mathematics learning in vocational education is contingent upon factors including

learner readiness, interface design and course design. Students' attitude towards mathematics appeared to influence their participation in web-based mathematical activities. Although computer skills and confidence are necessary for successful participation in web-based activities, students' attitude towards mathematics played a more important role in determining their participation.

The study also found that course design factors play an important role in affecting the teacher's and students' attitude and motivation in making use of web-based learning resources in a mathematics classroom. Rigid demands imposed by learning outcomes and assessment procedures of the VET curriculum appear to constrain students' learning and exploration with web-based activities. Comparison of attitude scores indicated that the treatment group students developed a significantly more positive attitude towards mathematics than the control group students. Although achievement scores of the treatment group did not vary significantly compared to control group, learning gains made by the treatment group were found to be qualitatively different.

The research has highlighted issues related to design and use of web-based mathematics learning in the vocational context and shown that web-based learning resources offer mathematics teachers opportunities for creating more engaging, authentic and collaborative learning experiences in their classrooms. However, educators need to recognise the challenge of bringing web-based learning to mathematics classrooms and realise that assessment is an integral part of teaching practice and it must reflect new dimensions of learning afforded by web-based learning activities

Chapter 1: Context of the Study

1.1 Background to the Study

In the new millennium teaching and learning of mathematics are facing new challenges in the Vocational Education and Training (VET) sector in Australia. Rapid progress and developments in new technologies have led to a transformation of workplace practices and research is showing that these practices demand an increasing degree of techno-mathematical literacies from workers (Bakker, Hoyles, Kent, & Noss, 2006). Research is also showing that workplace mathematics demands are very different from traditional mathematics taught in classrooms, and if we wish to prepare our students for future workplace needs we need to rethink about what we teach as mathematics and the way we teach it (Buckingham, 2001; Gunningham, 2003; Zevenbergen & Zevenbergen, 2004).

The ubiquitousness of the Internet and communication technologies is having significant influence on teaching and learning practices both in terms of what is learnt and how it is learnt. During the past decade a number of Commonwealth and State funded initiatives have pumped millions of dollars in building online and flexible learning capabilities in the vocational education sector in Australia. These initiatives have provided infrastructure to support access to new technologies, facilitated development of resources for online learning and supported professional development of teachers in the application and use of these new technologies. The Internet-based technologies offer unique opportunities and potential to support and enhance teaching and learning of mathematics and the research literature suggests that teachers of mathematics are only beginning to explore this medium in extending mathematics learning (Borba, 2005; Loong, Barnes, & White, 2002; Mavrikis & Macciocia, 2005; Yushau, 2006).

Australian students' performance in mathematics in primary and high school stages, as indicated by international studies such as the Third International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA), appears to be amongst the top for countries of the OECD and well above the international average (Department of Education Science and Training, 2003; Thomson & Bortoli, 2008; Thomson, Cresswell, & Bortoli, 2004; Thomson & Fleming, 2004). This is an encouraging sign and reflects positively on the efforts of education departments in the early years of schooling for mathematics and science. However, students' participation and performance in mathematics in the post-compulsory years of schooling is somewhat different. Reports indicate that the number of students opting for advanced mathematics subjects in senior years of secondary schooling is declining gradually with a corresponding increase in the proportion of students choosing an easier mathematics option (Bagnall, 2002; Forgasz, 2006a). This declining interest in pursuing mathematics in the senior secondary years is also apparent in the UK where enrolment in senior mathematics have been declining since year 2000 (Smith, 2004). One possible ramification of this trend is the lack of mathematical preparedness of students attempting vocational and higher education courses, as anecdotally reported by many teachers. It is not uncommon to find many TAFE teachers seeking extra tutorials and concurrent assistance to overcome this difficulty. This study emerges from a similar context and focuses on supporting and extending mathematics teaching through the development and use of an online learning environment.

1.2 VET Sector, E-Learning and Mathematics

The VET sector in Australia has undergone significant changes and reform during the past decade. These reforms have largely been influenced by economic factors emerging from the effect of globalisation and rapidly changing technology on industry. The globalisation and changing technologies are also seen as leading drivers for the increase in the skills base, competitiveness and productivity of Australian industry.

Prior to these reforms of the 1990s Australian vocational education was run as eight separate training systems across the eight states and territories with training providers having the main responsibility of content and delivery of these courses. Vocational education and training was to a large extent delivered by State funded TAFE colleges where liberal educationists argued that TAFE education ought to be primarily concerned with access and equity, second chance education and individual growth and development in education. At the same time educational rationalists contested this position and countered that the primary focus of TAFE should be on its economic and industrial purposes and on the needs of business and industry in modern economic times.

Reforms in the VET sector have led to the development of the Australian Quality Training Framework (AQTF) with nationally agreed standards and portable qualifications currently offered by more than 4000 registered training providers nationwide (Caven, 2005). The reforms have also made it possible for the development of industry defined competency outcomes, assessment guidelines and national qualifications in the form of Training Packages. The VET sector has seen a tremendous growth in the competitive training market with many commercial and private training providers now offering training package based qualifications. VET qualifications are also offered in schools and figures show that more than 11% of year 11 and 12 students are now doing VET as part of their schooling (Caven, 2005).

Another consequence of the implementation of Training Packages has been a significant shift in training from national curriculum based qualifications to restructured industry-endorsed training where competencies are expressed in terms of workplace functions and performance. In a Training Package, competency standards describe the skills and knowledge for a given task, which industry recognises as appropriate for competent performance. Achieving standards of competence can lead to a recognised national qualification based on the Australian Qualifications Framework (Boorman, 2001; Fitzpatrick, 2003). In this context mathematical and numeracy skills specific to particular industries are listed as units of competence within various training packages and this leads many training providers to offer specific mathematics modules as a pre-requisite and underpinning skills and knowledge for gaining qualifications within the framework of a Training Package. While there is debate about whether real workplace competencies can be achieved without the trainee being employed in a real workplace, teachers in institutional settings are gradually increasing work-based components in their courses. Teaching of mathematical concepts and skills under such fluid curriculum structures is a constant challenge for a TAFE based mathematics teacher.

The transition from accredited courses to qualifications based on Training Packages has had a significant impact on institutionally based training in terms of their program offerings, facilities and equipment and relationships with industry (Boorman, 2001). Due to very close alignment of many units of competence in Training Packages with workplace practices, training organizations have had to invest in facilities and equipment to provide industry realistic training and assessment requirements. The transition to Training Packages has also been reported to result in stronger links between institution and local industry and many training organizations have reported improved employment outcomes from their institutionally based training courses (Boorman, 2001). These changes have also prompted teachers to explore new approaches in teaching and adapt the teaching content of their program to meet the changing needs.

As an integral part of National Training Reform Agenda, public policy has also promoted the use of flexible delivery in vocational education and training (Flexible Delivery Working Party, 1992). In recent years a number of initiatives by Federal and State bodies have created a generous funding flow towards flexible delivery and online learning projects. The Australian Flexible Learning Framework 2000-2004 (ANTA, 2000) and Victorian Flexible Learning Strategy (2000) have promoted a rapid expansion of information technology infrastructure and have been responsible for a range of resource generation and professional development activities such as Education Network Australia (EdNA), TAFE Virtual Campus, Toolboxes, Flexible Learning Leaders and Learnscope. While on the one hand these initiatives have created an enthusiasm and encouraged many VET teachers to engage in creative innovations using online learning some researchers continue to express concern about assumptions made regarding learners' preferences and their readiness for flexible and online learning (Misko, 2000; Robertson, 2007; Smith, 2005).

Despite varying interpretations and definitions of flexible learning in research and policy documents the pervasive influence of the Internet and communication technologies have resulted in the use of terms such as online learning, e-learning and flexible learning interchangeably to mean the same thing. Australian studies from the VET sector show that a fully online option of flexible delivery where learners have little or no direct contact with teachers has achieved only limited acceptance and most institution based teachers and learners prefer to use online learning in a blended format where a mix of face-to-face learning and online learning is present (Brennan, 2003; Cashion & Palmieri, 2003).

Access to technology no longer seems to be a hurdle for a majority of learners and recent Australian Bureau of Statistics (ABS, 2006) data show that 60% of households are connected to the Internet with 52% having broadband connections in their home. A survey of first year university students also revealed that more than 70% of students report having unrestricted access to broadband Internet (Kennedy, Krause, Judd, Churchward, & Gray, 2006). But, despite easy access to technology and popular belief of the net generation's ease with new technology, research literature continues to show that students' relative comfort in using technology does not automatically translate into their readiness and interest in adopting the technology for their learning needs (Robertson, 2007). Educationists and designers of technology based learning environments now understand that merely presenting learning materials in sophisticated web-based environments is not enough to attract learners and guarantee its effective use. The role of the teacher in planning and successful implementation of online learning has been shown to be of critical importance (Cashion & Palmieri, 2002). In relation to mathematics learning there is growing evidence that teachers' responses to computers are strongly constrained by their beliefs about mathematics and teaching, and simply providing them with access and technical knowledge is likely to have a limited impact upon their practice. A more appropriate way to tackle this issue would be to develop programs where teachers are encouraged to move slowly away from their existing practices without changing their relationship with students. In other words, teachers need to be supported to adopt new practices that initially do not greatly alter the balance of relationships between them and their students (Norton & Cooper, 2001).

1.3 Rationale for the Study

The field of mathematics teaching and learning in the VET sector is under-theorised and under-researched (FitzSimons, 2003). A close alignment of vocational training with industry and work-based learning in the recent years has made mathematics teaching within TAFE settings highly fragmented and discontinuous (FitzSimons, 2003). Current mathematics learning in TAFE can be characterized in two broad categories – one where mathematics learning is directly aligned to the vocational context of industry and the other where it is part of a preparatory or further education curriculum. In the latter case pedagogical issues concerning mathematics learning are similar to the school sector, albeit in an adult learning context. For example, in Australia the Certificate of General Education for Adults (CGEA) conceptualizes mathematics learning on a developmental constructivist paradigm. Learning and assessment strategies for CGEA focus on developing a holistic mathematical knowledge base. But, in mainstream vocational TAFE courses mathematics learning is embedded within the units of competence of Training Packages. Often mathematical skills and knowledge embedded in these units of competence are taught by expert trade teachers who are highly competent themselves in solving mathematical problems but have no training or experience of teaching mathematics (FitzSimons, 2003). In some cases, in order to operationalise this embedded mathematics in units of competence, course managers and coordinators rely on specific modules on mathematics learning which are taught by a mathematics teacher and focus on a set of selected learning outcomes from a training package. In this scenario the learner is expected to have the pre-requisite mathematical skills necessary for developing and applying mathematical knowledge related to the industry. Often, learners with a poor background in mathematics and mature-age students returning to classroom learning after a gap of many years find it difficult to cope with the demands of these units of competence with embedded mathematical content and look for extra support and assistance. Teachers of mathematics programs within TAFE settings appear to be aware of the difficulties faced by students and acknowledge the importance of aligning their course content to contemporary industry needs. New learning technologies have the potential of extending the classroom learning beyond the time and space of the classroom and my research study is based on one such attempt at the design, development and implementation of an online learning environment and its use by teachers and learners in supporting and enhancing mathematics learning in a TAFE setting.

Recent developments in web-based programming have enabled creation of realistic and highly interactive online learning resources (Loong, Barnes, & White, 2002;

Mavrikis & Macciocia, 2005). In addition visual representation and interactivity afforded by the web makes it possible for abstract mathematical concepts to be presented in simulated activities to reveal their physical properties and constraints. Interestingly, “while physical objects become more abstract when modelled onscreen (e.g. science simulations), mathematical objects, already inherently abstract become more concrete” (Lester, cited in Gadanidis, Gadanidis, & Schindler, 2003, p. 325). This particular aspect of web-based mathematical interaction is expected to present learners opportunities for “deeper learning” arguably missing from competency based teaching in TAFE (Biggs, 1999). Another potentially valuable and unique feature of web-enabled technologies is their ability to provide communication opportunities via electronic mail, discussion boards and instant chat. This communication feature is now built into most online learning platforms such as WebCT, Blackboard and Firstclass and enables learners to communicate with teachers and other learners without barriers of time and space. Some web-based discussion forums such as Ask Dr Math (Drexel University, 2000) have successfully created a global community of teachers and learners who share their knowledge to support learning of mathematics on a global scale. In addition to interactive simulation and online communication forums, web-based learning resources are also able to offer interactive tutorials for practising basic arithmetic and algebra skills such as rounding up numbers and transposing equations. Availability of these free, easily accessible and potentially powerful learning resources can be very useful and effective for teachers and learners of mathematics but their successful integration in teaching and learning of mathematics requires careful planning, skills and support.

Use of computer-based technology is increasing in workplaces rapidly. In these increasingly technology rich workplaces employees have to work with new technologies and interpret and act on data representations. They have to show an understanding of functional mathematical knowledge grounded in the context of specific work situations (Bakker, Hoyles, Kent, & Noss, 2006).   Increasing automation and globalisation of trade has drastically reduced the number of traditional manufacturing and agriculture based jobs in western economies. New job roles require employees to have increased techno mathematical literacies and a level of understanding of mathematical concepts and skills relevant for solving work-based problems (Hoyles, Wolf, Molyneux-Hodgson, & Kent, 2002). A number of recent reports from the U.S.A., U.K. and Australia point to this emerging crisis in the demand and supply of suitably trained workers with appropriate skills in mathematics (Department of Education Science and Training, 2003; A. Smith, 2004; United States Department of Education, 2000). There are also clear indications of a dearth of qualified mathematics teachers due to more lucrative job opportunities for mathematics graduates in business, services and information technology industries (Stephens, 2003). In the field of vocational education there is an increasing concern about the widening disparity between the mathematics used in workplaces and the mathematics taught in classrooms. There is a greater demand for integration of workplace context and technology in curriculum to make the teaching of mathematics more relevant to the needs of business and industry (American Mathematical Association of Two-Year Colleges, 2002).

Considering the important role of new technologies in vocational education and training, government initiatives in Australia have invested generously in promoting and supporting the uptake of flexible learning and online learning and most of these initiatives have been directed towards supporting infrastructure, creating new teaching resources and the professional development of teachers. Research efforts in exploring online learning in VET have largely been funded through the same initiatives and focussed on a range of issues concerning access, uptake, quality, learners' expectations and experiences, professional development, online assessment, indicators of success and benchmarking (Brennan, 2003; Cashion & Palmieri, 2002; Choy, McNickle, & Clayton, 2002; McKavanagh, Kanes, Beven, Cunningham, & Choy, 2002; Oliver, 2001). Many of these researchers have found that online learning is an important option and students in vocational education and training value the flexibility of online learning. The uptake of fully online modes of study remains limited and most teachers prefer a mixed mode or blended approach where online learning is blended with face-to-face teaching to create a blended learning environment (Simons & Stehlik, 2004).

Despite these research efforts, little is known about learners' interactions with online learning in particular content areas and how new learning technologies are affecting the content and transforming the nature of classroom learning. Use of new learning technologies in mathematics teaching and learning is growing in the school and university sectors. But in the TAFE sector there are only a handful of documented efforts in integrating new learning technologies in teaching and learning of mathematics. Emerging literature on technology use in mathematics learning from the school sector is pointing towards a need to shift our focus of attention from technical artefacts to human factors in order to develop our understanding of how new technologies influence teaching and learning of mathematics (Goos, 2006; Lynch, 2006). In higher education and VET sector research a consensus is emerging on the important role of the teacher in integrating new technologies for effective learning and the transformative effect of technology on curriculum content (Borba, 2005; Cashion & Palmieri, 2002). Our understanding of teaching and learning of mathematics with the help of new technologies will be better served if research not only attempts to quantify the effect of technology on student outcomes but also investigates how students interact with new technologies, how mathematics learning is changed with the use of new technologies and how the teacher's role is affected in these technology supported blended learning environments. Considering these emerging views the current study aimed at responding to the following research questions:

1. What factors affect students' participation in a blended online learning environment?
2. How do students access and use a blended online learning environment?
3. How does using a blended online learning environment affect the teacher's role?
4. Does the use of online learning environment affect students' mathematical achievement?
5. How does the use of online learning environment affect students' attitude towards mathematics?

1.4 Objectives of the Study

At one level the objective of the study was to design and develop a web-based learning environment to facilitate and enhance mathematics teaching within a TAFE setting. At another level the research questions of the study aimed at investigating how students from a selected vocational mathematics module use blended online learning in mathematics, how the nature of mathematical learning and assessment, and the teacher's role, is affected by using blended online learning. The study also aimed to determine how students' attitude and achievement in mathematics are affected by blending online and face-to-face classroom learning.

One more objective implicit in the design of the study was to promote the use of new learning technologies in mathematics teaching and provide opportunities for inclusion of more authentic problem based tasks and cooperative learning. In this way the study included a practical orientation of action to bring about a change in practice of teaching of mathematics.

The study comprised of two cycles of design, enactment and analysis of an intervention aimed at supporting and enhancing the teaching and learning of mathematics. In the first cycle of the study collaboration between three mathematics teachers to design an online learning environment was followed by an enactment stage where the online environment was introduced to a range of mathematics classes. The design and enactment was premised on a number of conjectures about design and learning and these conjectures were tested and refined during the analysis and evaluation stage for the first cycle. The main objectives of the first cycle of the study were:

1. Carry out a comprehensive review of resources and tools available on the Internet to support teaching and learning of mathematics at the vocational education level;
2. Design and develop an online learning environment to support and enhance learning of mathematics in further and vocational education courses;
3. Trial the online learning environment with a number of mathematics classes in further and vocational mathematics course; and
4. Review the use of online learning environment by students and teachers and identify design changes and implementation strategies for future use.

The second cycle of the study comprised an in-situ trial of a customised online learning environment over a period of one full semester with a selected vocational mathematics class. During this cycle of the study the online learning environment in mathematics was customised for the selected business mathematics context and integrated with the WebCT platform. The face-to-face teaching of the module was blended with the online learning environment on WebCT and students were required to take part in online tasks as part of the learning activities for the module. The main objectives of the study during this cycle were:

1. Revise and customise the online learning environment in mathematics to suit teaching of a selected module in mathematics in a blended learning format;
2. Teach the selected mathematics module by using the online learning environment to enhance and support the learning of mathematical concepts and skills introduced in a face-to-face mode;
3. Identify factors that affect student participation in learning supported by an online learning environment;
4. Find out how the teacher and students use the online learning environment in a blended learning format; and
5. Find out if students' attitude towards mathematics and their achievement is affected positively by the use of online learning environment.

The use of the online learning environment in teaching was guided by the DISC model (Figure 1.1) developed by Coomey and Stevenson (2001) where they emphasise the importance of dialogue, involvement, support and control in online learning. According to the paradigm grid proposed by these authors, the second cycle of this study was situated in the north-west quadrant where the teaching remained teacher directed and the online learning was presented in a controlled and structured environment.

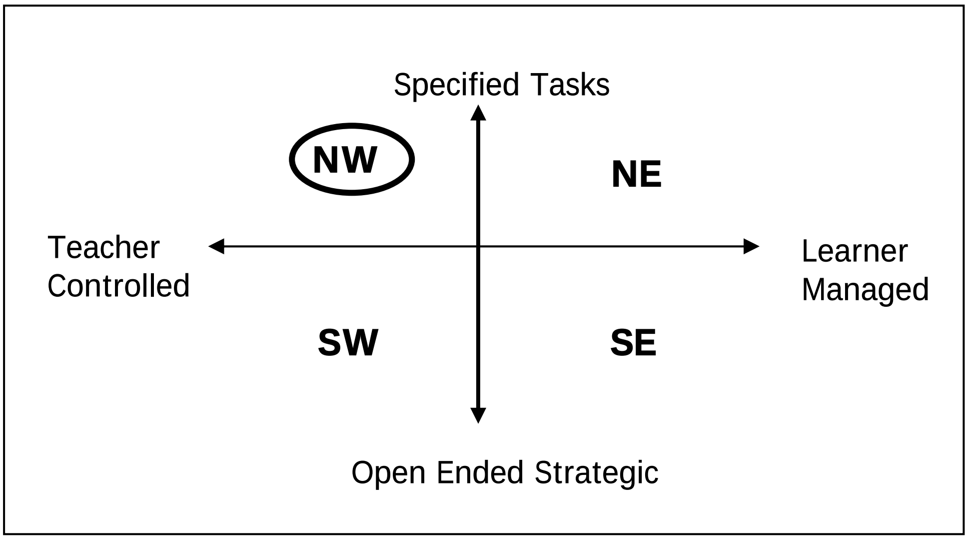

Figure 1.1. Paradigm grid for online learning. Adapted from Coomey and Stephenson (2001).

While the objectives of the study included the design and development of a technology rich online learning environment, the focus of the study was not on the technical aspects of technology intervention. As a researcher I was aware of the fallacy of the argument that pedagogical improvements inherently follow from the use of online technologies (Jackson & Anagnostopoulou, 2001). I was guided by contemporary research which suggested that the successful implementation of technology in learning requires the teacher's willingness, skills and creativity in using technology and whether the computer is viewed as a master, a servant, partner or an extension of self (Goos, Galbraith, Renshaw, & Geiger, 2003).

1.5 Expected Outcomes

The study is expected to lead to following outcomes:

1. Identification of personal, design, technical and organisational factors that affect students' participation in online learning in mathematics;
2. Identification of students' preferences in using an online learning environment in mathematics;
3. Identification of conditions that are likely to improve students' participation and learning in technology supported mathematics learning;
4. Recognition of the effects of blending online learning with face-to-face teaching on the teacher's role; and
5. Determination of the effect of technology intervention on students' attitude and achievement in mathematics.

1.6 Significance of the Study

The study is significant from the point of view that it adds to the body of research concerning the design, development and application of specialist online learning environments in supporting and enhancing mathematics instruction at the vocational education and training level. Considerable public attention in recent times has been drawn to the increasing techno-mathematical literacies required of the workforce for a highly technological society such as Australia. Both State and Federal governments in Australia have invested significant funding for adoption of new learning technologies and online learning to improve access and participation in vocational education and training (Department of Education and Training, 2006; Office of Post Compulsory Education Training and Employment, 2000; Oliver, 2001). In the vocational education context there is a growing concern regarding the lack of preparedness of learners to deal with mathematics content and the ever increasing gap between the traditional mathematical content and the mathematics knowledge and skills needed for emerging technology rich workplaces. Recent research reports and surveys concerned with the use of new technologies in vocational education have shown a growing acceptance of technology by learners and identified factors that contribute to the successful implementation of online learning. However, mathematics teachers are reported to be lagging behind in the use of new technologies in classrooms and research is needed to show how new learning technologies can be integrated to support and enhance the quality of mathematics learning.

This study involved the design and implementation of an online learning environment to support and enhance mathematics learning. The study is significant in the sense that it not only shows how a potentially useful learning environment is developed but also demonstrates how the teaching and learning of mathematics can be made more interactive, relevant and authentic by using it in a blended learning format in a mathematics classroom. Applying iterative cycles of intervention the study intends to identify factors that contribute to an effective use of the online learning environment in classroom teaching and how the mathematics teacher’s role is affected by using online learning activities in teaching.

The outcomes from this study will be able to assist vocational mathematics teachers in selecting and adapting online learning activities to enhance their classroom teaching and assessment practices. The study will also provide guidance to teachers to identify teaching and assessment strategies that are likely to foster a positive attitude towards mathematics and improve learners’ skills, knowledge and problem solving abilities in mathematics.

1.7 Conclusion

This study emerged from a perceived need of vocational and further education students to improve their mathematical skills and knowledge and become familiar with using technology as a learning tool. My main purpose in this study was to investigate how an online learning environment in mathematics can be designed and used to support and enhance students' skills and knowledge in mathematics.

The study was carried out in two cycles. In the first cycle the study focussed on the design and development of an online learning environment in mathematics and its trial, with a range of further and vocational education students, as a supplementary learning resource. Feedback and evaluation from this cycle was used to refine our understanding of students' use and participation in an online learning environment in mathematics. In the second cycle the online learning environment was customised for a particular business and marketing course in TAFE and trialled with a group of students. The study collected both qualitative and quantitative data to answer research questions.

In this first chapter of the thesis I have described the background of the problem and how this study was conceived as an attempt to support and enhance mathematics learning of TAFE students using new learning technologies. A description of the current state of mathematics teaching and learning in the vocational education and training sector with particular references to training packages and online learning in Australia has also been presented. Also presented in the chapter were the main aims of the study, the objectives of the two cycles of design and the enactment and analysis with a summary of expected outcomes.

Chapter 2 provides a comprehensive review of the literature relevant to the study with a particular focus on the use of the Internet in supporting mathematics learning. Current research on online learning in vocational education and the use of new learning technologies in mathematics teaching and learning is explored. In this chapter I attempt to identify the main design and technical issues concerning the development and use of web-based mathematics learning environments and their application in classroom learning. The literature review also shows how this study can provide new insights for the effective use of online learning environments in supporting and enhancing mathematics learning for TAFE students.

The main methodological approaches available are presented in Chapter 3 and the pragmatic epistemological orientation as a framework for this study is identified. This chapter includes a description of the design-based research methodology and how it suits studies of classroom based interventions where the purpose of the research is to actively participate in the design and implementation of an innovation in order to test and develop theories of instruction (Brown 1992). This chapter on methodology outlines the two main research cycles of this study and describes the design, enactment and analysis stages of each cycle in detail.

Chapter 4 and Chapter 5 provide a detailed account of the two research cycles as a description of practice. In Chapter 4 the first research cycle is presented to show the institutional, personal and curriculum context for the design and development of an online learning environment to support mathematics teaching and learning. This chapter gives a detailed account of the first research cycle comprising of a design and development stage, an enactment stage and a review and redesign stage. Chapter 5 presents an in-depth account of the second research cycle and shows how the online learning environment developed during cycle 1 was customised to suit the context of a particular vocational field and how online learning in mathematics was mixed with face-to-face teaching with a group of students for a period of one full semester. A comprehensive account of topics taught accompanied with the researcher's reflections and interpretations is provided in this chapter.

In Chapter 6 the analysis, interpretations and assertions emerging as a consequence of retrospective analysis of both qualitative and quantitative forms of data obtained during the design and enactment stages of the second cycle of this study is reported and discussed. In Chapter 7 I present a summary of conclusions and implications emerging from this study. I discuss the limitations of this research and provide guidance for future research. On a practical level I also present a list of suggestions for teachers aiming to integrate new technologies and web-based mathematics learning in their classroom instruction.

Chapter 2: Literature Review

2.1 Introduction

In this chapter a review of current literature related to the field of study is presented to justify the choice of topic for the research and how the methodology adopted is relevant for addressing the proposed research questions. The study has been influenced by research emerging from mainly three perspectives and this chapter will focus on these perspectives in separate sections. Firstly, in Sections 2.2 and 2.3 literature related to mathematics learning in the vocational education context and students' attitude towards mathematics is presented to highlight the context and relevance of current study. Secondly, in Section 2.4 a review of literature on theoretical underpinnings concerned with the application of new learning technologies in the teaching and learning of mathematics is presented to show their relevance for this study. Furthermore, in this section literature related to learning theories relevant to the design and teaching of mathematics with the help of new learning technologies is also presented to support and justify the methodology used in this study. Finally, the last section of this chapter, Section 2.5, is devoted to the issue of designing online learning environments for mathematics. This section focuses particularly on literature related to web-based learning in mathematics classrooms.

2.2 Mathematics in Vocational Education

2.2.1 Mathematics in Society

Mathematics occupies an important place in society and teaching and learning of mathematics has been an important part of school since ancient times (AAMT, 1996). Most ancient civilizations such as Hindu, Greek and Roman included elementary mathematics in their education system but it remained largely confined to male children of upper class and wealthy citizens (O'Connor & Robertson, 2000). In those days mathematical knowledge was considered a lesser intellectual pursuit than metaphysical, moral philosophy and religion because it was associated with practical and utilitarian ideas of everyday trade and calculations related to worldly affairs. For example, classical education of medieval Europe included teaching of mathematical fields of arithmetic and Euclidean geometry and apprentices of trades such as masons, money-lenders and merchants were expected to learn this practically oriented mathematics.

In contemporary society mathematics is considered a backbone for science and technology developments and mathematics has become an integral part of school curriculum. Mathematics content and teaching methods are constantly debated and governments take a keen interest in making sure that the quality of mathematics teaching is maintained in State-funded schools. In recent years many technologically and economically advanced countries have begun to monitor comparative performance of school age children in mathematics and science through surveys such as Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMMS). Results from these comparative studies are reported widely in the media and influence educational policy developments in concerned nations (Bosse, 2007).

Worldwide educational reforms have pursued development of standards for teaching and learning of mathematics. For example in the United States the National Council of Teachers of Mathematics (NCTM) developed new standards for teaching of mathematics in schools in 1989 to meet the needs of students entering a more technologically advanced and complex workforce (Crosswhite, Dossey, & Frye, 1989). The NCTM standards were further refined in 2000 with the publication of NCTM Principles and Standards for School Mathematics document (Bosse, 2007). The NCTM principles recognise that “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (National Council of Teachers of Mathematics, 2000, p. 11).

In the United Kingdom Professor Adrian Smith’s (2004) inquiry into post-14 mathematics education grew out of the concern that current curriculum, assessment and qualifications frameworks are failing to meet the needs of many learners and do not satisfy the requirements and expectations of employers and higher education institutions. One consequence of this report has been the establishment of a National Centre for Excellence in the Teaching of Mathematics (NCETM) in 2006, which aims to enhance the professional development for mathematics teachers in all education sectors in England.

In Australia the Statements of Learning for Mathematics (Curriculum Corporation, 2006) have been developed with a collaborative effort from States and Territories with an objective of serving as a nationally consistent framework for the development of new curriculum and reforming mathematics education. The statements highlight the dynamic nature of mathematics and note that:

> *Mathematics knowledge has been developed across cultures throughout history and continues to develop today. Mathematics education responds to social change, developments in mathematics, new technologies and new approaches to mathematics enquiry. (p. 2)*

The changing nature of mathematics and the need for mathematics curriculum to respond to these changing needs was also emphasised in the previous national statement on mathematics (Australian Education Council, 1990) which noted that the rapid growth of mathematics and new technologies were influencing the way mathematics is produced and applied and that access and success in mathematics is necessary for the economic well being of Australia. The statement predicted that demand for mathematically skilled people in Australia will rise but supply fall. The document noted that due to a shortage of skilled workers worldwide, Australia can no longer “expect immigration to fulfill our shortfall” (p. 15). Indeed, these predictions about the skills shortages in Australia have become a reality (Khoo, McDonald, Voigt-Graf, & Hugo, 2007). Another important aspect of the Australian Education Council’s National Statement on Mathematics was its clear endorsement of the use of technology in teaching mathematics. It pointed out that:

> *There have been considerable advances in computing software suitable for use in school mathematics. There is a range of ways in which computers can be used in mathematics classrooms including 'number crunching', data analysis, as a simulation device, graphics, symbol manipulation and spreadsheets. Each of these uses has implications for what is most usefully taught in mathematics and how it is taught. (p. 31)*

The ideas espoused by these national statements on mathematics have been central in guiding curriculum frameworks in mathematics such as the Victorian Essential Learning Standards (VELS) (VCAA, 2008). The VELS clearly outline that school mathematics needs students to be able to "demonstrate useful mathematical and numeracy skills for successful general employment and functioning in society and solve practical problems with mathematics, especially industry and work-based problems" (p. 4).

Concerned with the state of numeracy and mathematics learning in schools the Queensland government has produced a Framework for Action (Education Queensland, 2007) to support teachers of mathematics in offering high quality mathematics and numeracy programs. The Framework for Action aims at helping students develop capabilities to lead numerate lives and meet the numeracy demands of all learning areas of the curriculum. In this framework also, the ability to use technology in teaching and learning of mathematics is an important aspect of teacher's knowledge and pedagogy.

The Australian Association of Mathematics Teachers (AAMT) has adopted Standards for Excellence in Teaching Mathematics in Australian Schools in which it acknowledges that excellent teachers of mathematics have a strong knowledge base to draw on all aspects of their professional work. They also point out that these teachers are aware of a range of effective strategies and techniques for utilizing information and communication technologies in teaching of mathematics (Australian Association of Mathematics Teachers, 2006).

Although there is widespread recognition of the importance of mathematics in today's highly technological society research has also found that there is a highly visible trend of diminishing enrolments in mathematics courses in higher education (Forgasz, 2006a). Furthermore, although in secondary schooling there is an increased participation in learning and more students are staying on in schools to finish their senior secondary schooling, in terms of mathematics they appear to be opting for the easier mathematics option. One consequence of this trend appears to be that students enrolling in vocational education programs in TAFE courses often do not possess pre-requisite knowledge and skills in mathematics. There is a well recognised need in the sector to provide educational intervention and support to enable these students to succeed (Wilson, 2007).

In the context of post secondary vocational or technical education the American Mathematics Association of Two-Year Colleges (AMATYC) appears as a leading forum devoted to the issues of mathematics teaching and learning (FitzSimons, 2002a). The Organisation has more than 100 institutional members from the U.S. and Canada and has been committed to providing a national forum for the improvement of mathematics instruction in the first two years of the college.

The AMATYC has developed sets of standards for intellectual development, content and pedagogy to provide a foundation for mathematics teaching in the two-year college programs. The intellectual development standards include: problem solving, modelling, reasoning, connecting with other disciplines, communicating, using technology, developing mathematical power and linking multiple representations (AMATYC, 2005). The AMAYTC standards for pedagogy outline guidelines for instructional strategies in active student learning and include: teaching with technology, active learning, making connections, using multiple approaches, experiencing mathematics and interactive lecturing (AMATYC, 2005). The standards developed by AMATYC emphasise that technology should be an essential feature of mathematics teaching and learning and note that:

> *Technology continues to change the face of mathematics and affect the relative importance of various concepts and topics of the discipline. Advancements in technology have not only changed how faculty teach, but have also changed what is taught and when it is taught. The many types of technologies with varied uses can deepen student learning and prepare students for the workplace. (p. 11)*

In the vocational education sector in Australia, however, no such standards or national statements regarding the teaching and learning of mathematics can be located.
In Australia, mathematics teaching in the vocational education field remains a marginalised and isolated activity and decisions about curricula rest with industry training boards (FitzSimons, 2002a). Evidence from the field suggests that

experienced VET practitioners often draw upon their own resources to adapt existing curricula in mathematics to create innovative and meaningful ways of improving teaching and learning of mathematics.

The literature reported in this section highlights the changing nature of mathematics and how mathematics teaching and curriculum needs to respond to these changes and meet the challenges presented by the growing importance of mathematics learning for a modern society on the one hand and diminishing numbers of students enrolling in mathematics courses in post secondary education and training courses. Although policy level initiatives such as development of national standards are highly desirable there is a concurrent need for educational intervention and support that enables students to experience success in learning mathematics.

2.2.2 Workplace Mathematics

There is a growing gap between what is taught as mathematics in schools and what mathematics is needed at workplaces. Research from workplaces has shown that mathematics used in workplaces is highly context dependent and situated in the practices of the workplace (FitzSimons & Mlcek, 2004; Marr, 2007; Zevenbergen & Zevenbergen, 2004). Increasing use of technology has also made a significant impact on mathematics practices of workplaces. Research is showing that techno-mathematical literacy is needed in technology rich workplaces of today (Hoyles, Wolf, Molyneux-Hodgson, & Kent, 2002; Noss, Hoyles, Bakker, & Kent, 2005). These findings have direct bearing on vocational education programs where mathematics is taught to prepare the workforce for the future. If we want the gap between what is taught as mathematics in formal vocational training and what knowledge and skills of mathematics are needed at workplaces then we need to adapt our mathematics content and teaching approach to be more relevant to the current and future workplace.

Zevenbergen (2005) in a longitudinal study comparing numeracy practices of younger generation shop assistants (people aged 22 or less, referred to as Millennials by the author) with non-millennial employers and job placement workers noted that young participants were predisposed to use technology and were seen to “defer the cognitive labour to technology i.e. cash registers, computers, or calculators" (p. 7). She points out that the young workers' predisposition to use technology manifested in their willingness to use estimation and ability to problem solve more effectively than their employers and older peers. These findings have implications for training providers that continue to follow a traditional format and view the use of calculators as a form of "laziness and incompetence" (p. 9).

In relation to the mathematical needs of workers in a modern technological society there is a view that suggests that as new technologies make mathematics invisible most workers would not need to know much about mathematics. However studies of mathematical use in workplaces has shown that technology use is increasing and workers need to demonstrate different mathematical skills from those traditionally taught in school mathematics. Instead of having the fluency in performing explicit mathematical procedures using pen and paper workers are now required to show fluency with using and interpreting output from an IT system and software. They are also encouraged to demonstrate an understanding of the mathematical models deployed within the IT system in order to inform workplace judgements and decision-making (Bakker, Hoyles, Kent, & Noss, 2006).

In a research study focussing on how to enhance techno-mathematical literacy of workers at a finance enterprise selling mortgages, Bakker et al. (2005) observed that the mortgage provider despite acknowledging that sales employees were narrowly trained for future needs, pointed out that the company deliberately avoided training in explicit mathematical ideas underlying IT based financial calculations in order to avoid alienating most of their sales employees. In training sessions to enhance techno-mathematical literacy of sales employees the researchers adapted the idea of using customised spreadsheets to open up "black box" calculations for investigation because the process allowed for manipulation and exploration of variables (p. 6). The researchers noted that this way of learning kept algebraic formalism "encoded" within the spreadsheet structure in such a way that the learner could see rather clearly what the formalism was doing (p.9). The focus of training in techno mathematical literacy is to guide "learners to use mathematical ideas appropriately, rather than guiding them to do the explicit mathematical calculations involved" (p. 9).

In today’s highly technological society most financial services institutions are increasingly using online tools to help customers choose from a range of products and services. Many of these tools are based on sophisticated mathematical calculations taking place in the “black box”. Students currently doing vocational education courses in preparation for working in the finance sector companies will be required to use these online tools and sophisticated calculators in their everyday workplace practice. It therefore becomes imperative for vocational education programs to prepare students to meet the challenges they will face in technology rich workplaces of the future.

Workplace mathematics skills are context dependent and highly specific to particular contexts and it is not possible for formal training to include each situation and context. In this situation it also becomes critical that formal training consciously aim to help learners develop meta-cognitive strategies such as learning to learn, critical thinking, planning and problem solving (FitzSimons & Mlcek, 2004). Furthermore, mathematical knowledge and skills developed in school and vocational education play an important underpinning role in workplace numeracy practice. FitzSimons, Mlcek, Hull and Wright (2005) argue that workplace numeracy education cannot be approached from a traditional 'school mathematics' outlook (p. 9). In their workplace study these authors noted that numeracy in the workplace involves the practical application of rational numbers and the metric measurement system with contextualised approximations and estimations in critical calculations, often with other workers. They point out that workplace mathematics use differs markedly from the traditional conception of mathematics education as an “abstract, rule-bound, individual activity, with one correct answer (usually a number, an algebraic expression, or a standard graph), and where mistakes are temporary setbacks” (p. 6).

A number of studies focussing on mathematics learning and use from Australian workplaces confirm the view that mathematics used in industry is intertwined with technical expertise at all occupational levels. Research shows that employees at workplaces have more control over how they solve their problems compared with traditional classroom mathematics and the mathematical correctness or precision required for completing a task at workplaces depends on constraints such as time and money (Buckingham, 2001; FitzSimons, 2003; Marr, 2007; Zevenbergen, 2005).

The emerging understanding of how mathematics is used and applied at modern workplaces reported in this section has an immediate relevance for the design of learning in vocational education. Learners in vocational education and training need to be presented with opportunities to become familiar with, and use, artefacts from relevant workplaces. At the same time it needs to be recognised that every workplace context can not be incorporated into formal training because enterprises have become highly specialised. Therefore there is a need to include meta-cognitive strategies such as problem solving and critical thinking along with mathematical knowledge and skills (FitzSimons, 2003).

During this study, the development of a web-based learning environment to support learning of mathematics for vocational students aimed at enhancing techno-mathematical literacy of students by providing them the opportunity to use the online tools and calculators from real world contexts in classroom based mathematics learning. During teaching online learning activities were mixed with face-to-face mathematics instruction to promote the use of technology in solving mathematics problems and helping students develop meta-cognitive skills of critical thinking and problem solving.

2.2.3 Mathematics and Vocational Students

In recent times there has been an increased focus on the VET sector of education internationally. This is mainly in response to global economic change and government and industry now view VET as a major factor in the drive to be internationally competitive. Keating, Medrich, Volkoff and Perry (2002) point out that the VET sector provides great flexibility in course length, content, location and modes of delivery and it is seen as providing both industry-specific skills and more generic workplace skills. In response to a shortage of skilled workers to meet the needs of industry there is a renewed emphasis on invigorating technical and vocational education programs via increased funding for VET education, additional pre-apprenticeship places and opening new technical training centres (Department of Education and Training, 2006).

Interestingly while there is a renewed interest and a move to expand vocational education and training provision there is also a general trend of a declining number of students studying subjects like advanced mathematics, physics and chemistry in their senior years of secondary schooling (Department of Education Science and Training, 2003; Forgasz, 2006a). There is also a dearth of qualified mathematics teachers in the school sector and many students learn mathematics from teachers who do not have mathematics qualifications. Thomson and Fleming (2004) in their analysis of TIMSS data note that 30% of teachers teaching mathematics to year 8 students in Australian schools do not have either education mathematics or mathematics as their major area of study. It is a cause for concern for policy makers that an education that aims to stimulate curiosity, problem solving and depth of learning among school students fails to encourage them to continue with mathematics in their senior years of schooling and beyond (Department of Education Science and Training, 2003).

Historically students opting for vocational education programs in TAFE colleges are not the highest academic achievers. These students enrol in vocational education programs largely because they may have an aptitude for a practically oriented occupation or they may do a TAFE course as a pathway to higher education degree. However, Anderson (2005) has refuted the assumption that VET students enrol in courses mainly for extrinsic and work-related reasons. He notes that aspirations for personal growth and development and career change are common motivators for students' course choices in the VET sector particularly for students in the age group of 25 and above (p.12). In an Australian survey of VET students Anderson (2005) found that students' transition into VET courses appears to be non-linear and diverse. He found that in a significant number of cases they do not come to vocational education directly from secondary schooling. In this study the respondents came to VET from several other forms of education and training including school (17%), transitioning out of unemployment (10%), out of employment to education and training (42%), or into study from home based work (12%) (Anderson, 2005). The survey also shows that individuals opting for VET pathways typically follow zigzag trajectories, frequent interruptions or changes in direction. They use VET qualifications to navigate changing "career trajectories" during their working lives (p 9).

Young vocational education students also have to make a transition from school-based learning practices to adult learning practices of vocational education where they are expected to be more self-directed, autonomous and responsible for decision making (Choy & Delahaye, 2002). In the vocational education context the term andragogy is used which usually refers to learner-centred teaching practices as pioneered by Knowles (1980). Knowles' assumptions regarding andragogy are based on the disposition of adult learners and Choy and Delahaye (2002) articulate these as:

- The need to know: adults like to connect learning with their lives readily and prefer active learning which fits into the context of their life activities;
- The learner's self-concept: adults see themselves as individuals who have the capacity to make decisions for themselves;
- The role of learners' experience: adults possess life experiences which serve to express their self identity and form valuable learning resources;
- Readiness to learn: adults show a self-realisation of the need to learn;
- Orientation to learning: adults are motivated to learn because they understand the value of learning in enhancing their ability to address issues of their daily lives;
- Motivation: adults are generally intrinsically motivated to learn.

Most of these andragogy principles are reflected in VET sector learning and learners are expected to take responsibility for their learning in self-paced learning materials. Indeed, competencies listed in particular training packages are realistic and located in the context of real workplaces.

In a study aimed at finding out if young people aged 17-24 years enrolled in a VET course have an orientation to learning that benefits from andragogy practices, Choy and Delahye (2002) surveyed 266 young people enrolled in metropolitan TAFE colleges. They noted that young people preferred mainly the social aspects of andragogy but were less willing to accept the responsibility for learning associated with adult learners. They were also more inclined to view teachers as experts and transmitters of knowledge. These findings have clear implications for teachers involved with the learning of young adults at TAFE courses. Young adults seem to carry with them practices they are familiar with from their school years and simply expecting them to be able to take responsibility of their learning in VET through self paced and flexible learning formats is unlikely to be successful (Keith & Javed, 2004). In the research by Choy and Delahaye (2002) although young students indicated that they wanted to be treated like adults and showed a preference for a closer relationship with teachers, for structured course work and organised assessment procedures, their view of the teacher as an expert and responsible for directing their learning has important implications for this research. As mathematics teachers responsible for designing learning opportunities for young students we needed to find a balance between the andragogy principles that allow us to construct learning activities that offer relevance and opportunity for self-paced learning on the one hand and pedagogical needs of learners who expect teacher directed structuring of learning activities on the other.

The pattern of work and education also bears significant influence over participation and success of students in vocational education programs. It is no longer the case that students first undertake full time study and after completion of this study enter into full time employment. Current students hold part time and casual jobs while undertaking full time or part time post school studies in VET or higher education. In a national online survey of VET students enrolled at Registered Training Organizations in Australia, Anderson (2005) found that 67% of those enrolled in a full time VET course were engaged in casual employment whereas 74% of those enrolled in a part time VET course were engaged in full time employment. This trend of concurrent participation in work and education appears to be closely associated with the frequency of career change among individuals undertaking VET courses. Gabb, Milne and Cao (2006) point out that the personal choices made by students in relation to work and education are highly relevant and put pressure on educational institutions for more flexible delivery of educational products.

Another common assumption about vocational education students currently prevailing is that the young generation of today is totally immersed in technology. It is argued that today’s generation of learners, sometimes referred to as generation Y or Net generation (Anderson, 2005), has grown up with all the new technology to the extent that it is second nature to them. A second assumption accompanying this argument is that generation Y will be totally at ease with learning with new technologies and show a readiness to learn with these new technologies.

In a review of research on learner readiness to adopt online learning and flexible learning in the VET sector Robertson (2007) found that it can not be assumed that learners will automatically perceive that a technology they regularly use for non-educational purposes will be useful to support their learning. Review of research suggests that the popularity of technology on its own is insufficient to guarantee its transfer into educational use by generation Y learners. This observation is important for teachers in VET programs because, although young students may appear to be totally at ease with using computers and Internet technologies, to engage them in learning via new technologies needs careful planning when designing technology that will support their learning.

Research into the use of technology in mathematical tasks by children of the baby boomer generation (and younger) has found that they prefer to defer the cognitive labour of calculations and other mathematical thinking to technology. In a case study research Zevenbergen and Zevenbergen (2004) found that the need to calculate accurately by the young generation seems to be deferred to technological tools – computers, calculators, and other industry specific equipment. The skills of estimation are central to their work as is having an intuitive feel for a situation. The researchers note that the old skills of accuracy, meticulous mental calculations and measurement have been displaced by skills of estimation, problem solving, and use of technology.

This section on mathematics and vocational students highlights that VET students' motivation and preparedness to enrol in education and training courses varies greatly. It is also clear from these findings that a majority of VET students hold either full time or part-time jobs and prefer the flexibility of access to learning but the research also shows that many young VET students need teacher directed and well structured learning environments. These findings also show that young VET students may appear to be totally at ease with new technologies and it would be mistaken to assume that these students would automatically transfer this preference to technology for learning purposes as well. However, in terms of use of technology in mathematical tasks it appears that the younger generation prefers to defer the task of accurate mathematical computations to technology prompting the need for estimation and problem solving skills. These findings have implications for practices of teaching vocational mathematics where holistic thinking, problem solving, estimation, technology, and intuitive thinking will need to be included in curriculum planning and design.

2.3 Attitude towards Mathematics

Many students in vocational education, especially adult learners returning to study after a gap of some years, tend to show a level of mathematics anxiety usually arising due to their negative experiences of learning mathematics at school (FitzSimons, 1998). Students' perceptions that they can not understand mathematics and that it is a hard subject is linked to an image students have of mathematics as an abstract collection of rules and processes (Kaput, 1995). Anxiety in mathematics generally manifests itself in the form of feeling of tension, apprehension or fear (Ashcraft, 2002). This anxiety has the potential to lead to low self-confidence in doing mathematics and impact on the mathematical performance of learners. Confidence of learners in their mathematical abilities and their attitudes and beliefs towards mathematics affects learning of mathematics (Coben, 2003; FitzSimons, 2002b).

The literature on attitude towards mathematics draws on a range of theories and definitions of attitude. Aiken (2000) defines attitude as a "learned predisposition to respond positively or negatively to a specific object, situation, institution or person" (p.248). Attitudes are distinguished from beliefs in that attitudes are moderate in duration, intensity and stability and have an emotional content, while beliefs become stable and are not easily changed (McLeod, 1992).

Ma and Kishore (1997) conceptualise students' attitude towards mathematics as "an aggregated measure of a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (p. 27).

Lefton (1997) views attitudes as long lasting patterns of feelings and beliefs about other people, ideas or objects that are based in a person's past experiences and shape their future behaviour. Lefton identifies three dimensions of attitudes as cognitive, emotional and behavioural and points out that each dimension serves a specific function. The cognitive dimension of an attitude consists of thoughts and beliefs. The emotional dimension involves evaluative feelings such as like and dislike. The behavioural dimension of an attitude determines how people actually show their beliefs and evaluative feelings. In this study I was aware that vocational education students exhibit a wide range of attitudes towards mathematics based on their educational experiences and personal circumstances but my interest was in establishing how their enjoyment (emotional dimension) and their perception of value (cognitive dimension) was influenced by the implementation of an online learning environment to support classroom based learning.

The research literature on measurement of attitude towards mathematics provides an extensive range of measuring scales developed over the last thirty years. Fennema and Sherman (1976) attitude scales have been one of the most popular tools for measuring mathematics attitude of school age children. This scale has 108 items and takes about 45 minutes to administer (Barkatsas, 2005; Tapia & Marsh, 2004). The Fennema-Sherman Mathematics Attitude Scale is made up of nine subscales including Attitude towards Success in Mathematics Scale, Mathematics as a Male Domain Scale, Father/Mother Scales, Teacher Scale, Confidence in Learning Mathematics Scale, Mathematics Anxiety Scale, Effectance Motivation Scale in Mathematics and Mathematics Usefulness Scale. Although this scale has been used extensively a number of researchers have questioned its validity and the integrity of scores generated by these scales (Tapia & Marsh, 2004). As this scale uses statements appropriate for school aged children it was not considered appropriate for use with the students who were young adults in this study.

Another popular attitude scale designed to measure the attitudes toward mathematics is the Mathematics Attitude Scale (Aiken, 1974). This scale measures general attitude towards mathematics and comprises two subscales of 10 items each covering students' enjoyment of mathematics with items such as "mathematics is enjoyable and stimulating to me", and their perceptions of its value with inclusion of items such as "mathematics is a very worthwhile and necessary subject". The 20 items in this scale comprise half positive statements and half negative statements. The original scale includes Likert scale format but a revised version used by Drexel University (2001) uses a Yes/No format for response. The Aiken Mathematics Attitude Scale is reported to have a test/retest reliability of .94 (Bassette, 2004).

Taylor (1997) suggests that the relative simplicity and brevity of Aiken’s Mathematics Attitude Scale provides significant advantages to educators and researchers in the field. The scale has been popular with researchers in the post secondary and adult and community education. Recent studies by Chapman (2003), Bassette (2004) and Yushua (2006) have used this scale with pre-tertiary and vocational education students. I chose this scale for my study due to its relevance for tertiary level students and its simplicity and brevity for ease of administration and analysis.

Bassette (2004) used the Aiken’s Mathematics Attitude Scale to measure the attitude of mature age students enrolled in a developmental basic arithmetic course at Prince George's Community College in Maryland. A sample of 329 students enrolled in day and evening classes participated in the study. Students were given the Aiken Mathematics Attitude Scale at the start of the semester as pretest and again at the end of the semester as posttest. The study aimed to assess the difference of the initial and exiting attitudes towards mathematics and academic outcomes of students. The study also aimed at finding out if there was any association between initial placement test scores and students’ pretest attitude scores and final exam scores. Demographic variables such as age, gender and ethnicity were also used as criteria when comparing students’ attitudes and performance in placement and final examination.

Results on the Aiken attitude pretest showed that 61% of students scored 40 or less on a scale with maximum 80 points showing a low or negative attitude towards mathematics. Only 39% of students scored more than 40, showing a positive attitude towards mathematics in pretest. Overall comparison of pretest and posttest attitude scores showed a moderate association (r=.41) and pretest attitude scores of women were positively related to the placement score and the final examination score. The study found no significant difference in attitude between students who passed and students who failed. The study also reported that students aged 50 and above scored better marks in the final examination than other groups. In contrast students aged 21 and less scored less than other groups in the final examination. Overall Bassette’s

(2004) study shows only a weak association between attitude and performance in mathematics.

In a study of effects of blended e-learning on mathematics and computer attitudes in a pre-calculus algebra course in a pre university program in a Saudi Arabian university Yushau (2006) used the Aiken's Mathematics Attitude Scale to compare students' attitude at pre- and post- course stages. Along with mathematics attitude the study also measured computer attitude at pre-test and post-test stages. Seventy students from a prep year program participated in this experiment where three face-to-face teaching sessions per week were complemented with an online session where MATLAB and other online resources to support mathematics were available to students. Using a WebCT platform course material, solutions to past exam papers and quizzes were available for students. Some problems were posted on the course home page on a weekly basis for students to solve and submit online. In addition all course-related announcements were also made using the online home page. Results from the study compared pre and post attitude towards mathematics and also towards computers.

The study reported no significant difference in students' attitude towards mathematics and the mean scores at both pre and posttests suggest that students maintained a mainly positive attitude. However there was a slight decrease in the mean score for mathematics attitude at the posttest stage. On the computer attitude scale there was also no significant difference but surprisingly on two subscales, computer confidence and anxiety, students' post scores were significantly lower than the pretest level. Yushau (2006) suggests that because the university places more rigorous and higher standards than students expect compared to their high school studies they felt overworked compared to the other group who were taking the normal lecture in the traditional mode only. The study indicates that blended learning adds new dimensions to learning and students' preparedness to undertake online-based learning may play an important role in successful implementation. Also, traditional assessment modes and quality standards can make technology appear to be an extra burden rather than a means for exploration, learning and concept development.

In a pre-tertiary foundation course in Introduction to Quantitative Methods Klinger (2005) studied the profile of attitudes, anxiety and self-efficacy beliefs in mathematics using a pre-post survey with 160 students at an Australian tertiary institute. The study developed a 95-point survey by adapting items from three different attitude, anxiety and self-efficacy scales. Klinger found significant improvement in students' perceptions and beliefs of mathematics after nine weeks of teaching but noted that if students' tertiary education goals are blocked, or their progress impeded because of their perceptions of mathematics, it becomes necessary to first challenge their negative attitude and perceptions towards mathematics. It was noted that attitudinal negatives towards mathematics could fuel avoidance behaviour in students resulting in a diminished self-efficacy belief, heightened anxiety leading into withdrawal from mathematics learning. In vocational and further education courses also a similar trend is observed (Callan, 2005; Coben, 2003; Klinger, 2005) and one of the purposes of my study was to create a learning environment that creates opportunities for changing students' negative attitude towards mathematics.

In recent years a renewed focus on the significance of affective factors in mathematics learning has been highlighted by the emergence of a range of new instruments and scales for measuring attitudes towards mathematics. Tapia and Marsh (2004) have developed an Attitude Towards Mathematics Inventory (ATMI), which consists of a 49-item survey and includes self-confidence, value, enjoyment and motivation factors. The ATMI is designed particularly for secondary school students and items are suited to the context of school-aged students. With increasing application of technology in teaching and learning of mathematics new scales for monitoring students' attitude to learning mathematics with technology have also emerged.

Barkatsas (2005) developed a Mathematics and Technology Attitude Scale (MTAS) for middle secondary years students with the intention of including mathematics confidence, confidence with technology, attitude to learning mathematics with technology, affective engagement and behavioural engagement as five affective variables relevant to learning mathematics with technology. This 20-item scale consisted of five subscales with 4 items each. Trials of MTAS scale with 350 students from year 8 to year 10 classes from Victorian schools in Australia produced results that suggest strong or acceptable degree of internal consistency in each subscale. The scale is simple and brief and takes only about 10 minutes to administer but its usefulness is confined to cohorts in the secondary schools due to the specific references to graphic calculators and school context.

In the area of technology enriched mathematics learning at the undergraduate level a number of Australian researchers have been active in designing and testing affective measure scales and instruments. Fogarty, Cretchley, Harman, Ellerton and Konki (2001) developed an Attitude to Technology in Mathematics Learning Questionnaire to measure three affective factors – mathematics confidence, computer confidence and attitude to technology in learning mathematics. The Likert type measurement scale consisted of 34 items and focused on identifying and measuring attitudinal factors that mediated the effective use of technology in learning mathematics. In a study to validate the questionnaire it was trialled on a cohort of 289 students undertaking algebra and calculus course as part of their undergraduate studies in Education at a Queensland university. Cronbach's alpha internal consistency results from the study proved the reliability of the questionnaire to be satisfactory with a value ranging from .84 for Maths-Tech scale to .92 for computer confidence. Although this scale appeared to be relevant for measuring computer and mathematics attitude for the current study with VET students the length of the questionnaire and assumptions about students' experience of computer use in mathematics learning made it unsuitable for the cohort of TAFE students in this study.

Another Australian scale for measuring affective factors in mathematics learning with technology was developed by Galbraith and Haines (1998) and includes six subscales for factors including Mathematics Confidence, Computer Confidence, Mathematics Motivation, Computer Motivation, Mathematics Engagement and Computer Mathematics Interaction. Each Likert type subscale consists of 8 items with a total of 48 items for six scales. The items listed in the Computer Mathematics Interaction scale render it useful only when students have been exposed to computer based mathematics learning during a course and as such it is not useful to administer this scale as a pre-test. These scales provide a useful means for investigating students' attitude to computer use and to mathematics particularly in the context of undergraduate studies.

In a study of 1st year undergraduate linear algebra and calculus course where MATLAB was integrated into their learning Cretchley and Galbraith (2003) used a mix of computer and mathematics attitude scales (Fogarty, Cretchley, Harman, Ellerton, & Konki, 2001; Galbraith & Haines, 1998) to investigate students' perceived abilities and attitudes towards mathematics and computers both separately and interactively. Using data obtained from 196 students who took the pre-test and 82 students who took the full set of pre- and post-test and examinations Cretchley and Galbraith analysed the results to demonstrate associations between different affective and cognitive factors. The study found that mathematics attitudes (confidence and motivation) correlated strongly (r=0.65) with levels of achievement on a wide range of mathematics tasks. But computer attitude and mathematics attitude correlate weakly (r= .12). The study found only a weak correlation between computer confidence and motivation levels and performances generally on mathematics tasks in a technology rich learning environment. Mathematics tasks requiring use of technology were generally well done by the majority of the students – not only by those who were confident with, and enjoyed, using computers. The authors noted that computer confidence was a poor indicator of the likelihood of a mathematics student feeling empowered by the use of technology in learning mathematics. It appears from this study that harnessing students' computer confidence for improving mathematics learning is a continuing challenge especially for those students who seem to show high computer confidence but low mathematics confidence.

Another commonly held belief amongst mathematics educators is that interest and enjoyment in mathematics learning would naturally lead to improvement in mathematics performance. But research shows that the relationship between interest and enjoyment in mathematics and mathematics performance is not clear-cut. Analysis of results from PISA study (Thomson, Cresswell, & Bortoli, 2004) shows only a weak relationship (r=0.19) between the interest and enjoyment in mathematics and mathematics literacy performance in Australian students. This weak relationship does not appear to be surprising because it was not significantly different from the OECD average and was similar to other English speaking countries. Interestingly, three of the highest performing countries - the Netherlands, Finland and Korea - had means of the interest and enjoyment in mathematics index lower than the OECD average showing that students in these countries performed at a high level in mathematics but expressed less interest and enjoyment in mathematics than students in other OECD countries. However two other high performing countries Hong Kong and China had scores similar to OECD average. The PISA study used a four-item scale to measure interest and enjoyment in mathematics as an indicator of intrinsic motivation to study mathematics. The interest and enjoyment scores obtained in the PISA study illustrate the difficulty of associating interest and enjoyment measures with performance in mathematics tests with any consistency.

Although some researchers have challenged the validity of the assumption that positive attitude towards mathematics leads to better performance in learning mathematics because it may well be the case that students' better performance in mathematics leads them to demonstrate a more positive towards mathematics (Galbraith, Pemberton, & Cretchley, 2001), there is a wide body of research that supports the view that positive attitude towards mathematics and performance correlate strongly. Cretchley and Galbraith (2002) point out that the mathematics teachers' goals of cognitive gains must be tempered by attention to affective outcomes. They assert that if a learning experience is unpleasant for the student, any gains in cognitive achievement and performance may be offset or diminished by attitudinal losses and this dislike or feeling of inadequacy may deter the student from studying further in the area. This critical balance between cognitive and affective goals is particularly important for contexts with adult learners in vocational education where an undue emphasis of obscure traditional mathematics content learning could easily 'turn off' a student who may not have pleasant experiences of learning mathematics from school years.

The literature review in this section has highlighted the fact that affective factors such as attitudes and motivation play an important role in mathematics learning. Students' confidence, attitude and beliefs towards mathematics are known to affect their performance (Coben, 2003) but the relationship between attitude in terms of interest and enjoyment and performance in mathematics is not clear cut (Thomson, Cresswell, & Bortoli, 2004) . Still, a large volume of research supports the view that positive attitude towards mathematics and performance in mathematics correlate strongly and it is important to maintain a critical balance cognitive and affective goals. This study draws on the view that research on mathematics education can be strengthened by integration of affective issues in the studies of cognition and instruction. Consequently, the study incorporates a design experiment where an online learning environment was developed and used to assist the teacher in creating opportunities for making improvements in both affective and cognitive domains of learning. Considering the significance of affective outcomes for mathematics learning this study monitored students' attitude towards mathematics by using pre- and post-test measures and implementing teaching strategies to foster positive attitude towards mathematics.

2.4 Technology and Mathematics Learning

Although the use of computers in teaching and learning of mathematics education research has been reported for a long time now it is only in the recent past that problem solving, simulation and micro-world based programs have emerged that try to engage learners in a context based problem solving situation and aim to teach mathematical concepts. The development of network based computing, the Internet and the world wide web offers new opportunities for the use of computers in mathematics teaching and learning and research into the range of ways and effectiveness of these new technologies is only beginning to emerge. In the following sections I will present a discussion on the theoretical perspectives relevant to the application of new learning technologies on the teaching and learning of mathematics with relevance to the vocational education and training context. In the first part I have discussed the work done by the Cognition and Technology Group at Vanderbilt (1992) in developing the theory of anchored instruction and the work of Collins, Brown and Newman (1989) in developing the model of cognitive apprenticeship as useful theoretical perspectives framing the design and development of my research project. The section on theoretical perspectives is followed by a discussion and analysis of current perspectives on the role and impact of new learning technologies on mathematics learning. In the final part of this section a discussion on research literature related to the role of the teacher in technology enriched teaching and learning of mathematics is presented to identify a relevant framework for analysing the teacher's role in the current research.

2.4.1 Theoretical Framework

Based on theoretical foundations of constructivist learning and situated cognition John Bransford (1990) guided the development of a model of learning known as anchored instruction at the Cognition and Technology Group at Vanderbilt (CTGV) where technology rich environments are used in learning mainly science and mathematics (CTGV, 1992). Anchored instruction ideas evolved in response to the inert knowledge notion associated with traditional approaches to instruction in education literature from the early twentieth century. Inert knowledge is knowledge that can usually be recalled when people are explicitly asked to do so but that is not used spontaneously in problem solving contexts even though it is relevant.

Anchored instruction uses technology-based innovations to situate learning in realistic problems, allowing students to experience the same professional dilemmas as faced by experts in a given field. Using learning environments where problems are structured to be factually authentic with real data and performances authentic with realistic tasks that might be faced by a novice being apprenticed to be an expert, anchored instruction shows similarities with case-based learning (CTGV, 1992). In anchored instruction stories or situations presented are meant to be “explored and discussed rather than simply read or watched” (CTGV, 1992, p. 249). It is similar to problem-based learning but does not expect students to do first-hand research into resources external to the learning environments. Instead anchored environments typically embed all of the information needed to solve the problem and make it easier for learners to interact in environments with limited time or limited resources.

Development of anchored instruction environments derives from the situated cognition framework (Brown, Collins, & Duguid, 1989) and relies on the use of authentic tasks in learning contexts. The authors noted that authentic activities are commonly "ordinary practices of the culture" (p. 34). In anchored instruction authenticity of tasks and activities can be analyzed from a number of perspectives. At one level it relates to the authenticity of objects and data being used in the learning context. At another level it involves the degree to which the task that students are asked to perform are authentic. At yet another level authenticity relates to the process of doing mathematics, that is how does the process of doing mathematics in class differs from how mathematics is done in real life contexts. Resnick and Klopfer (1989) pointed out that everyday settings are different from school settings in a number of ways. The school environment places more emphasis on individual work whereas in everyday work settings people have to perform tasks in collaboration with others. There is generally an emphasis on abstract reasoning in schools whereas in everyday settings contextualised reasoning is used more often. In addition, the school environment focuses more on 'mental work' whereas everyday work settings use tools to solve problems. Anchored instruction uses technology to bring the elements of contextualized everyday settings into classrooms by encouraging authentic tasks and collaborative work in solving problems that are located in real life contexts.

When a subject is taught in multiple contexts and includes examples that demonstrate wide application of what is being taught, people are more likely to abstract the relevant features of concepts and to develop a more flexible representation of knowledge (Gick & Holyak, 1983 as cited in Bransford, Brown, & Cocking, 1999, p. 50). But overly-contextualised knowledge may not support effective transfer, as shown by studies at Cognition and Technology Group at Vanderbilt (1992). For example in a study students learned mathematical concepts of distance-time-rate in the context of solving a complex case involving planning for a boat trip. The findings indicated that when students learned only in this context, they often failed to transfer flexibly to new situations. (CTGV 1997, as cited in Bransford, Brown, & Cocking, 1999, p. 50). The transfer of learning literature suggests that the most effective transfer may come from a balance of specific examples and general principles, not from either one alone (Bransford, Brown, & Cocking, 1999).

Although the anchored instruction model of learning presents real opportunities for authentic learning in classrooms and has been shown to promote higher order thinking skills, the requirements of standardised curriculum in educational settings pose a challenge for educators willing to adopt this model. The technology-based macro-environments proposed in anchored instruction are more suited to school-aged children. However, the concept of using technology to bring authentic tasks, real life contexts, collaborative learning and problem solving are important elements of anchored instruction and have helped in guiding the development of the online learning environment for this study.

Another theory and model of learning that informed this research project is known as cognitive apprenticeship (Collins, Brown, & Newman, 1989). Also based on constructivist approaches to learning and situated cognition, the theory of cognitive apprenticeship argues that people who have mastered certain cognitive skills often fail to make them explicit when teaching to novices. It holds that it is important to bring these "tacit processes into the open, where students can observe, enact, and practice them with help from the teacher" (p. 460). Cognitive apprenticeship methods require externalisation of processes that are carried out internally by experts. According to Collins, Brown and Holum (1991) cognitive apprenticeship methods of instruction include:

> Modelling: it involves an expert's performing a task so that the students can observe and build a conceptual model of the processes that are required to accomplish it.
>
> Coaching: it consists of observing students while they carry out a task and offering hints, scaffolding, feedback, modelling, reminders, and new tasks aimed at bringing their performance closer to expert performance.
>
> Scaffolding: it refers to the supports the teacher provides to help the student carry out the task. It may involve the teacher in executing parts of the task that the student cannot yet manage and gradual fading and removal of supports until students are on their own.
>
> Articulation: it includes any method of getting students to articulate their knowledge, reasoning, or problem-solving processes.
>
> Reflection: it involves enabling students to compare their own problem solving processes with those of an expert or another student and ultimately, an internal cognitive model of expertise.
>
> Exploration: it involves pushing students into a mode of problem solving on their own. Exploration is a natural culmination of the fading and supports.
>
> (Collins, Brown and Holum, 1991, p. 14)

In this model, while modelling, coaching and scaffolding are teacher-led activities in making explicit the content and process, the articulation, reflection and exploration stages involve learners in actively refining and fine-tuning their thinking and problem solving.

According to Collins, Brown and Newman (1989) cognitive apprenticeship involves the retooling of a traditional apprenticeship model for the teaching and learning of cognitive skills particularly aimed at teaching students the thinking and problem solving skills involved in school subjects like reading, writing and mathematics. Similar to anchored instruction articulated by Bransford (1990) cognitive apprenticeship also places a strong emphasis on the context of learning. Taking a lead from traditional apprenticeship practice where apprentices learn skills in the context of their application to realistic problems within a culture focused on and defined by expert practice, cognitive apprenticeship also encourages students to carry out tasks and solve problems in an environment that reflects the multiple uses to which their knowledge will be put in the future. The situatedness of learning in cognitive apprenticeship allows students to understand the purposes or uses of the knowledge they are learning, engages them in actively using knowledge rather than passively receiving it and offers them an opportunity to learn about the different conditions under which their knowledge can be applied (Collins, Brown, & Holum, 1991).

The proponents of the cognitive apprenticeship model of learning point out that computer technology enables creation of learning environments that can help in visualising and “realising the abstraction in practice” (Collins, 1988, p. 5). In addition, the computer also enables us to develop learning environments that “mimic situations in the real world” that are otherwise impossible to realise in a classroom (Collins, 1988, p. 6).

The web-based learning environment developed in this research project used these ideas to provide modelling and scaffolds with the help of computer simulated tasks for students. In addition the classroom practice adapted by the teacher also involved elements of cognitive apprenticeship by using modelling and coaching practices that allowed students to observe the details of problems solving and thinking processes associated with mathematical problem solving.

2.4.2 New Technologies in Mathematics Learning

In a review of technology applications in learning of mathematics in secondary schools Goos, Stillman and Vale (2007) identify a number of features of technology that afford learning opportunities in mathematics. They contend that new technological tools in mathematics provide opportunities to learn from observing patterns, instant feedback and making connections between multiple representations. In addition, the Internet offers opportunities to explore simulated or authentic data and offers the potential to extend learning by finding, sharing and communicating mathematics.

Citing numerous examples of spreadsheet and graphic calculator use Goos, Stillman and Vale (2007) point out that the “technology makes it possible for students to see connections between multiple representations of a concept” enabling the student to gain an understanding and insight into an abstract mathematical concept (p. 78). The authors also highlight the usefulness of the Internet in teaching mathematics by pointing out that the Internet now makes available an enormous range of authentic data sets that allow learners to investigate mathematical problems using real life data sets. They also indicate that the Internet offers many useful sites where students can work with dynamic images of various kinds. Access to these dynamic images allows students to interact and manipulate these images in a virtual environment to develop an understanding of symmetry, transformation and other special concepts (p. 80). Another key feature listed by Goos, Stillman and Vale (2007) is the use of the Internet as a networking tool which makes it possible for learners and educators to collaborate and combine their efforts to solve mathematical problems and share their knowledge and experience with others.

In terms of effective teaching with the use of computer technology, Goos, Stillman and Vale (2007) assert “pedagogical content knowledge which enables teachers to create mathematical representations that connect students with subject matter is at the heart of teaching effectively with technology” (p. 100). They make it clear that “knowing how to use computers” is not enough to teach effectively with technology and teaching and learning of mathematics with technology entails much more than technical efficiency with computers.

Bransford, Brown and Cocking (1999) pointed out that new technologies, which include the Internet and web-based applications, provide opportunities for creating learning environments that extend the possibilities of old, and offer new possibilities, but warns that technologies do not guarantee effective learning. They suggest that new technologies can be used in five ways:

- to create new opportunities for curriculum and instruction by bringing real-world problems into the classroom for students to explore and solve. For example, connecting students with experts in the field and using interactive multimedia for learning
- to serve as scaffolds and tools to help students solve problems. Such as interactive simulators, calculators and virtual modelling
- to make it easier for teachers to give students feedback about their thinking and for students to revise their work. Network technologies for communication help make thinking visible.
- to connect classrooms to community both locally and globally.
- To expand opportunities for teacher learning.

Bransford, Brown and Cocking (1999) also noted that when teachers learn to use a new technology in their classrooms, “they model the learning process for students; at the same time they gain new insights on teaching by watching their students learn” (p. 195). Bransford’s ideas have continued to influence development and research of rich multimedia microworlds in teaching and learning in subject areas such as science and mathematics (Etheris & Tan, 2004; Shyu, 2000). One of the early examples of technology use in context for mathematics learning using Bransford’s principles of anchored instruction comes from the development of a series of video disc based learning environments titled Jasper Woodbury Problem Solving Series (CTGV, 1997). Developed for school-aged children this project demonstrated how technology could be used to create interactive learning environments that present students with challenges and require them to understand and apply important concepts in mathematics.

Some fifteen years ago in a review of the role of technology in mathematics teaching and learning Kaput and Thompson (1994) visualised three aspects of electronic technologies that had the potential to enable a deep change in the experience of doing and learning mathematics. They identified interactivity, control and connectivity as three sources of power of new learning technologies. Interactivity offered by new learning technologies allowed learners to engage with, and manipulate, the learning environment in ways previously not possible in computing. The control available to designers of learning environments allowed them to “engineer constraints and supports, create agents to perform actions for the learner, make powerful resources immediately available to aid thinking or problem solving, provide intelligent feedback or context sensitive advice and control physical processes from the computer” (p. 679). The connectivity power of new technologies makes it possible to link teachers to teachers, students to students, students to teachers and the world of education to the wider world of home and work. Indeed, studies of computer use in mathematics classrooms in recent years are reporting a significant decrease in the use of mathematical programs, but a corresponding increase in the use of the Internet and spreadsheets (Thomas, 2006).

Ainley and Pratt (2006) pointed out that access to technological tools can support new approaches to the design of pedagogical tasks and at the same time provide new insights about the nature of mathematical understanding. They argue that technology offers us opportunities not only to teach the same curriculum in new ways but also to challenge fundamentally the current sequencing of some topics. Citing research from classroom use of contextualisation in mathematical tasks the authors claim that in many cases the supposedly real-world settings in classrooms are unable to achieve the desired outcome as the objectives of the task identified by the teacher may be quite distinct from the one perceived by the learner. Cooper and Dunne (2000) as reported in Ainley, Pratt and Hansen (2006) indicate that in order to engage appropriately with the mathematical focus of a contextualised task, pupils have to understand complex but implicit rules about the extent to which they should attend to features of real-world settings. Ainley, Pratt and Hansen (2006) argue that providing tasks that may superficially offer authenticity by resembling out of school activities, such as setting up a play shop in the corner of a classroom to encourage some mathematical learning are unable to provide the structure and constraints faced in a real shopping experience.

According to Ainley, Pratt and Hansen (2006, p. 29) *purpose* and *utility* are two important characteristics of learning environments. *Purpose* refers to the perceptions of the pupil and a purposeful task is defined as “one that has a meaningful outcome for the pupil, in terms of an actual or virtual product, or the solution of an engaging problem”. According to the authors, the *purpose* creates the necessity for the learner to use the ‘target knowledge’ (Brousseau’s term as cited in Ainley and Pratt, 2006) in order to complete the task. It may involve using existing knowledge in a particular way or constructing new meanings through working on tasks. *Utility* of mathematical ideas relates to the notion that mathematics learning encompasses not just the ability to carry out procedures, but the construction of meaning for the ways in which those mathematical ideas are useful. In the framework proposed by Ainley, Pratt and Hansen (2006) *purpose* and *utility* are closely connected because “appreciation of the utility of mathematical ideas can best be developed within purposeful tasks” (p. 30).

Using the notion of ‘planning paradox’ in the context of task design in computer based Microworlds and learning environments for mathematics learning, Ainley, Pratt and Hansen (2006, p. 24) contend that if teachers plan their lessons from tightly focused learning objectives, the tasks they set are likely to be ‘unrewarding for the pupils and mathematically impoverished’ but if teaching is planned around engaging tasks the pupils’ activity may be far richer but less focussed and difficult to assess. The authors offer three levels of resolution to the planning paradox. Firstly, the mathematics education in the school sector needs to rethink how to approach curriculum content to address content focus and motivation. Secondly, the contextualisation of mathematical activity needs to relate school and ‘real world’ experiences to stimulate a sense of purpose. Thirdly, attention needs to be paid to the sorts of tools that teachers offer pupils whilst they work on the task. The affordances of these tools shapes the way pupils are able to pursue the teacher’s plans and understanding.

Although developed with relevance to school based teaching and learning of mathematics the notions of purpose and utility are very important for the teaching of mathematics in the context of vocational education. With a more direct connection of vocational education to industry it is not difficult to locate the utility of mathematical concepts developed, but the issue of the ‘planning paradox’ remains a challenge for teachers of vocational mathematics when competencies and standards need to be carefully articulated and assessed.

Research by Trouche (2003), Lagrange (1999), Artigue (2002) and Hoyles, Noss and Kent (2004) provides another important perspective on the integration of digital technologies in mathematics learning. This perspective derives from work conducted in a range of quite different situations including activities with adults in workplaces and with students in classrooms and outlines the notions of instrumental genesis, orchestration and situated abstraction (Hoyles, Noss, & Kent, 2004).

The notion of instrumental genesis refers to the mutual transformation of learner and artefact in the course of constructing knowledge with technology. It contradicts the dominant opposition that exists between the technical and conceptual dimensions of mathematical activity where technology is conceptualised as a tool and technical artefact that releases the student from technical activity in order to focus on mathematical concepts (Artigue, 2002). Instrumental genesis is based on the notions of artefact and instrument where instrument is conceived as a psychological construct that a person operationalises in activity with an artefact in order to carry out some task (Hoyles, Noss, & Kent, 2004). According to Artigue (2002) instrumented activity involves two processes – instrumentalisation and instrumentation. In the process of instrumentalisation the subject shapes the artefact for specific uses and in a simultaneous process of instrumentation the subject is also shaped by actions with the artefacts. The “dialectic by which learner and artefact are mutually constituted in action is referred to as instrumental genesis” (Hoyles, Noss, & Kent, 2004, p. 313). The phenomenon of instrumental genesis offers a new insight into thinking about the use of technology, including web-based learning resources, in teaching of mathematic.

Another important element in the integration of technology in mathematics classrooms is the element of orchestration. The term as proposed by Trouche refers to the process of “external steering of students’ instrumental genesis” in order to enhance their learning of mathematics (cited in Hoyles, Noss, & Kent, 2004, p. 316). An example of orchestration reported by Trouche cited by Hoyles, Noss and Kent

(2004) is how the architecture and organization of a mathematics classroom is presented. It involves the way the technology is configured to connect students, the way students sit in the classroom and the decisions regarding which technologies should be switched on or off in order that individual instrumented actions can become the object of the collective as well as individual reflection and discussion. While recognising the importance of Trouche's formulation of instrumented orchestration Hoyles, Noss and Kent (2004) placed a stronger emphasis on the role of interactions among learners and the role of technology in mediating these interactions. They highlight the importance of forming collaborative communities in classrooms that encourage sharing of different perspectives. The authors noted that computer based collaboration has been found to "encourage a shift in relationship between teacher and student and –under suitably managed circumstances with appropriate tools -enhanced task based interactions between students and between students and teachers". They argued that technology being the medium plays an important role but it is students who 'breathe life' into the technologies and rebuild the mathematical structures for themselves by means of their actions on them (Hoyles, Noss, & Kent, 2004, p. 318). In this study it was important to pay attention to orchestration elements such as the design of the web-based learning environment as well as the organization of online activities to enable instrumented actions of students and follow it up with individual reflection and group discussion with the use of a discussion board.

Contrary to the conventional approach to learning where knowledge and skills are developed first and applied to problem solving subsequently, technology rich learning environments provide the possibility of learners working with concepts that they may not yet understand. Hoyles and Noss (cited in Ainley, Pratt, & Hansen, 2006, p. 29) referred to this idea as 'using before knowing…' and claim that understanding emerges through activity. They argued that learning through use empowers students to learn mathematics in much the same way as learning in other natural contexts such as learning to read and write. This approach stands in contrast to the conventional approach in which the pupil rarely experiences using mathematics in meaningful ways (Ainley, Pratt, & Hansen, 2006). The use of online tools and calculators in exploration and problem solving activities with real life situations in this study was aimed at allowing students' conceptual understanding to emerge through their exploration and use of these tools.

With increasing prevalence of calculators, computers and networked technologies in mathematics learning another idea that has gained currency is the notion of affordances (Brown, Stillman, & Herbert, 2004; Watson, 2003). Gibson (1977) articulated affordances as relationships between objects and actors involved in interactive activity. Greeno (cited in Brown, Stillman, & Herbert, 2004) extends the notion of interactive activity and claims that affordance is “a property of whatever a person interacts with in the environment but this property must interact with a property of the person so as to support an activity” (p. 121).

Brown, Stillman and Herbert (2004) have pointed out that interactions between learners and technological devices necessarily involve both the ability of the learner and the affordance of the technology. They claim that it is these two elements that combine to determine the potential of the interactions in any given situation. Drijvers (2003) noted that the extent to which affordances of any technological tool can be realised in the classroom depends not only on the affordances of the technological tool but also on the way these affordances are managed by the teacher. Research has also shown that the teachers’ conception and representation of technological tools can easily transform affordances into constraints if the technological devices are used as a ‘black box’ rather than for exploration and sharing of ideas (Doerr & Zangor, 2000).

Yet, based on a design study of using computer modelling to teach algebra, Kennewell (2001) reported that constraints are not the opposite of affordances. He claimed that in technology rich learning environments constraints can be constituted as complementary to affordances, and within an educational setting learners can be deliberately constrained in order to facilitate desired action. For example, the teacher could alter available affordances and constraints of a technological environment so that the gap between these and learners’ abilities allows intended learning to occur (Kennewell, 2001). Despite the fact that the research literature on affordances of technology in mathematics learning is predominantly based on the application of graphical calculators and computer based software as learning environments, the principles involved are equally applicable to the design of web-based learning environments to support mathematics learning in vocational education. For example, providing navigational constraints in web design so that students are able to use desired links from a website directly and not become distracted by irrelevant pieces of information allows a teacher to use affordance of web-based resources for novice users more effectively (Gerber & Shuell, 1998).

Addressing the issue of technology mediated learning in the context of secondary school mathematics learning Goos, Galbraith, Renshaw and Geiger (2003) contended that technology as a tool is integral to mathematical practice of teachers and students and electronic technologies such as computers and graphic calculators offer new opportunities for students to communicate and analyse their mathematical thinking. They point out that "technology can foster conjecturing, justification, and generalisation by enabling, fast, accurate computation, collection and analysis of data, and exploration of mulitiple representational forms (e.g., numerical, symbolic, graphical)" (p. 74).

Drawing on socio-cultural theories (Vygotsky, 1978) of learning Goos et al. (2003) asserted that technology is a cultural tool which mediates thinking and reasoning in the context of classroom. Technology as a cultural tool mediates learning in two ways. First, it serves to amplify existing classroom tools for learning by speeding up calculations or by verifying results obtained by pen and paper calculations. Second, it transforms learners' thinking through technology-mediated interactions and leads to re-organising of cognitive processes. Goos et al. (2003) offer an example of this cognitive reorganisation by citing that "use of spreadsheet and graphing software can alter the traditional privileging of algebraic over graphical or numerical reasoning" (p. 75).

While acknowledging the instrumental genesis approach (Guin & Trouche, 1998) where students' interactions with technological artefacts were assumed to have "transformed the material tools into an instrument of mathematical thought that reorganised their activity", Goos et al. (2003, p. 76) conceptualised the role of technology differently and place a greater emphasis on interactions that occur between teachers and students, amongst students and between people and technology. Based on a 3-year longitudinal study investigating the role of electronic technologies in supporting students' exploration of mathematical ideas, and in mediating their interactions with teachers and peers, Goos et al. (2003) put forward a new analytical framework where they described classroom use of technology with the metaphors of *master, servant, partner* or *extension of self*. Based on varying degree and sophistication to which teachers and students interact with technology in their mathematical learning these differing perspectives are articulated by the authors as follows:

Technology as master: Technology can be labelled as a *master* when teachers' and students' knowledge and usage of technology is limited to a narrow range of operations relying on their technical competence (or lack thereof). In this formulation students are likely to develop dependence on technology because their lack of mathematical understanding prevents them from evaluating the accuracy of the output generated by these technological tools.

Technology as servant: Technology can be framed as *servant* when it is used only as a fast and reliable replacement for mental or pen and paper calculations. In this formulation the tasks of the classroom remain unchanged and technology is used as a supplementary tool to amplify cognitive processes. Students perceive technology as helpful in large and repetitive calculations because they can be carried out more quickly and efficiently and useful in reducing calculation errors and checking answers. Technology serves as a *servant* when it simply supports the preferred teaching methods and does not allow for creativity and exploration of ideas.

Technology as a partner: Technology serves as a *partner* when it is used creatively to "increase the power students exercise over their learning" (p.79). In this context the use of technology involves creative and exploratory tasks that facilitate understanding and help in cognitive re-organisation based on exploration of different perspectives. Furthermore, technology is seen to act as a *partner* when it mediates mathematical discussion in the classroom.

Technology as extension of self: Technology is projected as an extension of self when users incorporate "technological expertise as a natural part of their mathematical and/or pedagogical repertoire." (p. 80). In this expression of technology students use and integrate a range of technological resources in building their mathematical models and arguments. The sophisticated application of computers and calculators in solving mathematical problems forms an “extension of the individual’s mathematical prowess” (p. 80).

Although Goos et al. (2003) focussed on technology mediation in the context of secondary school mathematics and the use of graphing calculators and computers with mathematical software, their findings have theoretical and practical implications for mathematics teaching and learning for all sectors. They have shown that technological artefacts such as computers and calculators are not neutral objects and have the potential to reshape the interactions between teachers, students and the technology. Web-based technologies offer additional power to classrooms to influence this interaction. Teachers have an important role to play in designing and supporting technology mediated learning experience for students where the role of technology is designed to shift from technology as master to technology as a partner and possibly even as an extension of self.

In this section the review of the application of new learning technologies in teaching and learning of mathematics has highlighted the complexities in developing a clear understanding of the role of new technologies in mathematics learning. While researchers agree that the new technologies afford and offer new possibilities for learning there are also clear indications that use of technologies do not guarantee effective learning. An important aspect regarding the role of technology emerging from this review is that learning with technology is a two-way process and the role of technology is not limited to releasing students from technical activity in order to focus on mathematical concepts. Mathematics is also transformed with the use of technology. Another important point emerging from this review is the important role of the teacher in altering the affordances and constraints of the technological environment to foster effective learning of mathematics. This review of literature related to the application of new learning technologies in mathematics allowed the current research study to construe the blended online learning environment with the view that understanding of mathematics emerges through activity where technology is not seen as a *master* but as a *servant* and a *partner*.

2.4.3 The Teacher's Role

Research has consistently shown that the teacher plays a central role in the educational process, be it the behaviourist tradition of transmission of knowledge or a post-modern social constructivist model of experiential learning (Buzeika, 1996; Cashion & Palmieri, 2002; Hattie, 2003). Research reports from the vocational education sector in Australia report that that the teacher also plays a critical role in online learning, and teaching styles that facilitate online learning in vocational education are strongly linked to teachers' attitudes and their use of the medium (Brennan, 2003; Cashion & Palmieri, 2002). Stehlik, Simons, Kekham, Pearce and Gronold (2003), researching the professional development needs of vocational education teachers for flexible and online learning, reported that in order to deliver online programs well developed skills in writing, communicating, interpreting, conveying meaning and providing logical concise information are just as important as technological skills, such as the ability to use email, the Internet and PowerPoint applications. They pointed out that the design and development of online courses however, does require a specific set of technical skills, as well as certain administrative and organisational skills. Brennan (2003) contended that the teacher's role is critical in an online environment and technical, facilitation and management skills of teachers need to be combined in particular ways to suit the student, the content and the medium.

Robertson (2004) examined the practices of four TAFE teachers who used online technology in their classroom practice and found that these teachers adopted, applied and integrated online technology into their teaching practice in ways that supported their preferred teaching principles and did not have a negative impact on his or her teaching practice. In this study the selective adoption of features of online technology was demonstrated by the selective use of group email, bulletin board and computer marked assessments. One teacher used group email for communication with and between students as it aligned with her preferred teaching principle of developing a community of learners while another teacher's preference for using computer marked tests supported her desire to implement reduction and repetition as a teaching strategy. The study provided a detailed look at how a teacher's self-declared preferred teaching principles are reflected in the selection and application of technology into their teaching practice.

Considering the role of teacher in computer facilitated learning in the post secondary context Berge (1995) proposed a useful model where the teacher’s role was categorized as pedagogical, social, managerial and technological. Bonk, Kirkley, Hara and Dennon (2001) applied this framework in online learning in higher education and identified practices that are likely to assist in the success of online learning, including blended online learning where web-based learning is mixed with traditional face-to-face teaching.

According to Berge’s framework the pedagogical role of the teacher is concerned with teaching and facilitating education processes for developing understanding of key concepts, ideas, and skills. In the managerial role teachers deal with organizational, administrative and procedural tasks and issues concerned with teaching in an online supported environment (Berge, 1995). In the social role teachers aim at promoting a friendly environment and a sense of community amongst learners and in the technological role they resolve technical issues related to course design and implementation (Bonk, Kirkley, Hara, & Dennen, 2001; Teles, Ashton, Roberts, & Tzoneva, 2001). This framework recognizes the range of issues teachers need to deal with when teaching in a technology supported learning environment and appears to be useful for a detailed analysis of the teacher’s role in a blended teaching and learning environment.

In a mathematics classroom, when integrating new learning technologies with traditional face-to-face learning, the issues of teachers’ technical skills, access to resources, organizational and structural support and their own instructional beliefs play an important role in effective design and implementation of technology supported learning (Ertmer, Addison, Lane, Ross, & Woods, 1999; Forgasz, 2006b; Handal, 2004).

According to Smith and Lovat (1995) the teacher’s instructional beliefs refer to the set of assumptions and ideas they hold with regards to the teaching and learning process. The curriculum and these set of assumptions are known to influence teachers’ practice and play a mediating role between the curriculum and instructional practice. Although Handal (2004) found obvious manifestations of constructivist and behaviourist orientations in teachers' instructional beliefs and practices, other studies have shown that this dichotomy is not clear cut and the nature of the relationship between teachers' mathematical beliefs and instructional behaviour is dialectical and highly complex (Buzeika, 1996; Clarke, 2005).

Research has also reported barriers to technology implementation in mathematics classrooms in terms of first and second order barriers (Ertmer, Addison, Lane, Ross, & Woods, 1999). The first order barriers are concerned with practical issues such as availability of hardware and software, availability of time to prepare instructional tasks and administrative support. The second order barriers relate to teachers' instructional beliefs and attitudes concerning adoption and use of technology in the classroom. In this research the authors concluded that the second order barriers are crucial in determining the success of technology use because even when first order barriers are removed technology implementation can be severely affected by barriers such as teachers' beliefs and attitudes.

Similarly Jackson and Anagnostropolou (2001) pointed out that improvements in learning through online approaches, when observed, are generally the product of reflective teachers who have conceptions that encourage them to develop effective teaching interventions regardless of technology rather than a feature of particular online pedagogy such as discussion groups or interactive exercises or hyper-linked resources. They assert that arguments attempting to claim that pedagogical improvements inherently follow from the use of online technologies are dangerously misleading. This argument has found widespread support in research literature (Biggs, 1999; Cashion & Palmieri, 2002) and especially in reference to mathematics learning Lynch (2006) pointed out that a lot of rhetoric surrounding the use of new technologies in schooling "overestimates the degree of agency that a technological artefact may have and fails to account for the agency of human actors, the effects of existing systems and institutions, and the complexity of interactions that influence how new technologies are used" (p. 33).

Goos (2006) argued that simple notions of access and use are inadequate for developing an understanding of the role played by technology in mathematics teaching and learning. She claimed that teachers' interpretations of access to technology are based on their beliefs about what is beneficial for students and feasible in the light of their own experience and expertise and institutional context.

Focusing on pedagogy and the nature of teachers' professional learning,, Goos (2006) adapted Valsiner's framework (1997) to analyse the interactions between teachers, students, technology and the teaching learning environment. Drawing on socio-cultural theories of learning, this framework places emphasis on learning as a product of interactions with other people and materials and tools situated in a particular learning environment. It extends the concept of Zone of Proximal Development (ZPD) originated by Vygotsky to include two more zones – Zone of Free Movement (ZFM) and Zone of Promoted Action (ZPA). While Vygotsky referred ZPD to the gap between learner's current capabilities and the potentially higher level performance that can be achieved with appropriate assistance, the ZFM and ZPA relate to the social setting and the goals and actions of participants.

Applying the notions of ZPD, ZFM and ZPA to technology enhanced learning of mathematics in the school sector Goos (2006) explained that the ZPD involves elements such as skill and experience in working with technology, pedagogical knowledge related to technology integration and general pedagogical beliefs; the ZFM applies to issues such as access to hardware, software, curriculum and assessment requirements and students' motivation, behaviour and abilities; the ZPA deals with issues such as professional development and represents the efforts of a more experienced or knowledgeable person in the promotion and development of new skills. According to Goos (2006) "for learning to be possible the ZPA must be consistent with the individual's potential (ZPD) and must promote actions that are feasible within a given ZFM".

While Berge's (1995) framework to describe teacher's role in technology supported learning focuses on skills, knowledge and responsibilities of teachers and how technology implementation adds new dimensions to the role of teacher, Goos' (2006) framework of analysing the teacher's role focuses more on analysing the interactions that occur within a school-based learning context. In discussing the teacher's role in technology supported mathematics learning I think it is important to explore not only how the technology adds new dimensions to a teacher's role but also how the interactions within the learning context support or inhibit effective integration and use of technology. Both these frameworks are useful for analysing the teacher's role in technology enriched mathematics learning and have guided this research in describing and analysing teacher's practice.

2.5 Online Learning Environments in Mathematics

Advances in modern technology have enabled educational developers to create increasingly sophisticated and powerful tools for teaching and learning of mathematics. Computers and graphics calculators are now able to use software programs that have enormous potential to transform the content and nature of mathematics education (Forgasz, 2006b; Goos, Stillman, & Vale, 2007). During the past few years newer and more sophisticated mathematics software such as Derive, Maple, Mathematica and Geometer's Sketchpad have become available in both secondary and post-secondary teaching of mathematics. There is no doubt that these technological tools and software can be effective and useful in teaching and learning of mathematics but their accessibility by students both in educational settings and in their own homes has been restricted by costs and stringent licensing issues (Loong, 2001; Wang, Kajler, Zhou, & Zou, 2003).

Mathematics educators and researchers have been interested in exploiting the potential of Internet based technologies for mathematics education for some time now and one can find an increasing number of mathematics related websites and interactive learning resources on the web. Software developers of mathematics learning have also realised the importance of providing content on the web and have extended the functionality of their stand alone software products to be web enabled. For example Mathematica and Cabri Geometry software are now available in WebMathematica and CabriWeb versions for a web-based interface (Loong, 2001; Martinez, Barcena, & Rodriguez, 2005; Wang, Kajler, Zhou, & Zou, 2003). In the following sections I will discuss the design and development issues in producing mathematics learning content on the web and how current research and development is breaking new grounds in producing interactive content for web-based mathematics learning. Later in the section I will also report on selected research from the school and higher education sectors where the web is used in teaching and learning of mathematics.

2.5.1 Designing Mathematics Learning on the Web

Loong (2001) in her study presented a topology of mathematics learning objects on the web identifying two main categories – the resources type and the communication type. The learning objects falling under the category of resource type are mainly those objects that aim to explain and engage the learner in some form of mathematical content. Loong (2001) notes that interactivity of resources is the key discriminator in their educational usefulness and categorises these resources into three groups: Feedback systems, Exploratory Investigations and Games. She points out that non-interactive resources related to mathematics have been appearing from the early days of the Internet and serving varying purposes. These non-interactive resources have included materials like research articles, math history, lesson plans, archives of word problems, geometrical drawings, statistical tables and data, math jokes and various other static pieces of information related to mathematics. Communication technologies of the web offer another type of learning objects in mathematics. Math discussion forums, archives of questions and answers, and postings on various topics and levels in mathematics education use the features of the web to create a community of learners. The number of interactive, non-interactive and communication-based learning resources have been expanding both in quality and quantity since the publication of Loong’s taxonomy, and according to recent estimates (Handal, Handal, & Herrington, 2006) currently there are more than 500 individual websites for teaching and learning mathematics. However, research in the area of publishing of mathematics content on the web and teaching of mathematics with Internet based technologies has been reported to be a difficult and more challenging task compared to other humanities based disciplines.

In a study of student attrition in mathematics e-learning courses in the United States Smith and Ferguson (2005) have shown that mathematics teachers experience considerably greater difficulties in communicating mathematics in a web-based environment than teachers of other subjects, since most online course management systems do not support mathematical notations and diagrams. In a study comparing attrition rates in online courses with face-to-face courses at the State University of New York the authors used a simple survey to obtain quantitative data on students' enrolment and attrition from mathematics and non-mathematics related courses. From 138 responses obtained from online courses and 1246 responses obtained from face-to-face courses they noted that 32 online courses and 57 face-to-face courses were mathematics related. In terms of attrition the study found that the attrition rate from online mathematics courses (mean 0.31, SD 0.22) was significantly higher than non-mathematics courses (mean 0.18, SD 0.14). However, in face-to-face courses attrition rate for mathematics related courses (mean 0.05, SD 0.06) was very similar to non-mathematics courses (mean 0.05 SD 0.1). Although the students participating in this study were self-selecting, the findings point to a very obvious issue of difficulties in communicating mathematics in an online learning environment.

Smith and Ferguson (2005) reported that mathematics teachers in their study had to go through a three step process in order to post a mathematical notation on a web page – first they had to use a program like WebEq or MathType to generate a file with math notation, secondly, they had to save the file as an image file and finally they had to upload this image file on their web server to enable them to place this notation on the web page. They think that this process of importing mathematics notations into online documents made communication in online math courses extremely awkward. The issue of communicating mathematics in an online environment is a serious one and has affected uptake of online learning in a fully online mode. Smith and Ferguson (2005) also report that newer versions of online Learning Management Systems such as Blackboard and Firstclass have now integrated WebEQ plugins for writing mathematical notations and expressions but user familiarity and difficulties in learning new symbols and routines for online mathematics continue to pose problems for students.

Mavrikis and Macciocia (2005) report the development of a web-based system to support learning of mathematics in the United Kingdom. Designed for students needing extra assistance in their mathematics learning in undergraduate programs this web-based learning environment aimed at addressing the commonly perceived issue of growing deficiency in mathematical skills amongst students and the need for universities to take steps to address this problem.

Using Java applets and Java server-based interactivity this web-based learning environment offers HTML based text pages with embedded interactive objects on selected mathematics topics. These embedded objects are designed to provide visualisation of abstract concepts with animation and simulation and aim to create a dynamic learning environment for the learner. The WALLIS system also claims to support a feedback mechanism in order to avoid the need for a teacher to explain the task. The system uses interactive applets to communicate with a feedback frame to provide task specific hints. The authors have developed this web-based system only as a prototype and piloted it with a small group of undergraduate students. The system appears to follow an instrumental pedagogy where the use of content and interactivity on the web is used to clarify and explain mathematical concepts to students, in particular those concepts that are fundamental in students successfully undertaking a science and engineering degree.

Mavrikis and Macciocia (2005) while acknowledging the potential of this system to support mathematics learning concede the need for more research on the development of a feedback mechanism for learners to enable the development of a more detailed user model that tackles students' actions and online help with the system more effectively. Lack of quantitative or qualitative data from this project also points to the need for a systematic study of student interactions with web-based learning materials in mathematics and how these resources can be effectively integrated to support and enrich mathematics learning.

Advances in web programming with Java and XML tools and increased compatibility of Internet browsers to deal with specialised plugins to display mathematical objects have enabled developers to create web ready learning objects in mathematics. One such development from the field of vocational education in Australia is an innovative online support system designed to help in mathematics learning of vocational education students in Australia (Kavadias, 2003). Offering just-in-time learning assistance to students studying VET courses from the Building Industry Toolbox this online resource, branded as Your Online Learning Assistant (YOLA), delivers mathematics learning activities to students as they engage with online learning in their chosen vocational module.

A collection of learning objects to support this system contains activities from eleven topics including angles, area, conversions, fractions, length, measuring, multiplication and division, multiplying and dividing by ten, percentages, ratios and scale. These eleven learning objects are interactive and 'text-light' to support the needs of the young target audience enrolled in trade and vocational courses from the building industry.

In this resource, learning objects are presented to a learner only in the context of their vocational learning task. For example a student working with a building industry toolbox when learning about mixing mortar will be presented with a supplementary learning object on ratios by YOLA because the meta-tag for ratios is listed for the topic of mixing mortar. In this way the online support resource aims to offer just-in-time learning and practice in mathematics and avoids presenting a long list of topics for students to choose the desired activity.

As reported by Kavadias (2003) YOLA is not seen as a replacement of teacher input or intervention but it is rather seen as a first line of support to sustain an online learning experience, and as a teaching tool. One key element of this online resource was to create a way to deliver just-in-time support. One of the key design features of this resource was that it used XML metadata instead of 'tagging' pages in existing resources. This design feature meant that adding the Learning Assistant (YOLA) to an existing resource required only the addition of one XML file rather than redeveloping pages of existing content making the online support content more portable. However YOLA and other metadata tools would not be able to match terms if one developer has a resource described by the term ‘ratio’ and a second resource is tagged by the term ‘ratios’ or ‘proportion’.

Despite considerable investment of resources in the development of the resource there is no published work available on the effectiveness of YOLA on a practical level and the extent to which students and teachers have actually adopted the system to benefit from the potential it offers.

Apart from individual efforts from members of the mathematics education community in designing and developing mathematics content for web-based education a number of institutions have also come to the forefront of interactive content development for use on the web. In this regard a significant contribution is made by a University of Utah through its National Library of Virtual Manipulatives project (National Library of Virtual Manipulatives, 2008). The National Library of Virtual Manipulatives (NLVM) offers a library of uniquely interactive web-based virtual manipulatives or concept tutorials for mathematics instruction particularly suited to k-12 curriculum. These tutorials are similar to learning objects and use java programming to offer interactivity for the learner. One of the primary aims of these interactive manipulatives is to help students visualise mathematical relationships and applications. This project has produced a large number of virtual manipulatives to teach mathematics topics including number operations, algebra, geometry, measurement, data analysis and probability. Furthermore, these Java based manipulatives are freely available to anyone from their website nlvm.usu.edu and do not require any special plugins for viewing in popular Internet browsers such as Internet Explorer or Mozilla.

Another institutional effort comes from the Learning Federation initiative by Australian and New Zealand governments (The Learning Federation, 2007). This initiative aims at producing a large range of interactive learning objects for school subjects including mathematics and numeracy. The Learning Federation has also developed a vast repository of more than 4000 learning objects and made it available free to Australian and New Zealand educational organisations. Managed by the Curriculum Corporation Australia this project has been a major initiative in online content development of a large number of learning objects that aim to involve teachers and learners in interactive learning activities. These learning objects are designed to be usable in educational settings as elements within larger units of work that may comprise other digital and non-digital materials. For example selected learning objects can be embedded in a website developed by a teacher.

A quasi experimental study by Freebody and Muspratt (2007) to evaluate the uses and effects of the learning objects in teaching of mathematics and science topics in 28 schools from Australia and New Zealand found that there was no reliable significant effect for learning objects use in mathematics. Both control and treatment groups achieved comparable performance across the board in almost every topic area covered during the study.

As noted by Freebody and Muspratt (2007, p. 62) the experimental findings and the site visits of their study suggests the “likely futility of attempting to make a simple case for or against the efficacy of learning objects, learning management systems, or their combination”. They point out that most significant educational problems are not soluble simply by the provision of better technologies. They point to the need for more detailed, curriculum-specific and task-specific trials, research, and formal evaluation. The authors are keen to suggest that the research and development effort should now be directed to how learning objects can afford new interactional features and thereby new kinds of learning, and how those features can be put in place, in various ways, by teachers in various teaching contexts.

While learning objects developed by the Library of Virtual Manipulatives and the Learning Federation projects use latest technologies to create interactive multimedia content in mathematics that is usable by teachers and learners in a web-based learning environment, they are not customisable by individual teachers to suit their particular contexts. Once developed as a unit of web-based activity these learning objects cannot be edited or customised by teachers who wish to use them in their particular classrooms. However, this particular issue of teacher control in learning objects is being addressed by a project based at Kent State University.

The Institute for Computational Mathematics at the Kent State University in the United States is developing a Web-based Mathematics Education (WME) system to provide interactive mathematics content on the web that is easily portable and customisable by teachers (Wang, Kajler, Zhou, & Zou, 2003). Historically web pages using Hyper Text Markup Language (HTML) have not supported mathematical expressions for web publishing and as a result interactivity generated by CGI scripts, Javascript and similar programming languages has had problems in displaying mathematics calculations and expressions interactively on the web. The team working with WME framework has developed a mark-up language known as MeML. In the development of mathematical content for the web, the WME system uses open Internet technologies with MeML, HTML and MathML tags to create web sites that can produce mathematical expressions and figures and does not depend upon generation of image files for mathematical expressions using programs such as MathType (Zou & Wang, 2006).

The WME system supports mathematical formulas through MathML, interactive geometry objects through SVG (Scalable Vector Graphics), and a distributed mathematics assessment system called DMAS. The WME system focuses on interoperability and customisation of web-based mathematics content. Zou and Wang (2006) claim that WME content can be readily combined to form different lessons and modules on the web. One important feature of these WME learning objects is that once they are developed they can be edited by classroom teachers to suit different contexts and in this way WME content for the web is claimed to be more advanced than other web-based mathematics content currently available (Wang et al., 2008).

Currently WME system is being trialled in teaching mathematics in two secondary schools and one community and technical college in the United States and initial findings have been reported in conference presentations (Wang et al., 2008). These trials have been collecting data from teachers and students regarding the implementation of WME system in actual classroom situations to remove the bugs and improve the system. It can be argued that by allowing teachers of mathematics greater control over editing and customisation of content the WME system would help in extending the zone of free movement (Goos, 2006) of teachers and lead to the development of web-based learning that encourages students to make sense of mathematical ideas by building rich connections to their existing knowledge and allows for the context in which tasks are developed to be meaningful for them (Wang et al., 2008).

This limited review of the developmental stages of mathematics learning on the web highlights the difficulties and challenges faced by early adapters and teachers in designing and communicating mathematics through html programming. However, use of Java and JavaScript programming in subsequent years has allowed the development of interactive simulations and online tools for mathematics learning on the Internet. More recently, developments like the WME system and the Library of Virtual Manipulatives have also made mathematics teaching and learning on the web much more accessible. Although the WME framework was not available during the designing and development of the online learning environment for my study, CGI and Java based interactive objects to support and enhance mathematical understanding of TAFE students were used. Our web content relied on images generated by MathType to display mathematical expressions that were incorporated with mostly static content for describing mathematical models and concepts. In addition the online learning environment for this study also made use of communication capabilities of the Internet to engage in writing and communicating mathematical ideas related to classroom activities. As recommended for further investigation by Freebody and Muspratt (2007) through the development and trial of this online learning environment in mathematics for TAFE students this study made an attempt at exploring how the interactional features of mathematics on the web can be put in place in a particular teaching context and how it affects students' learning.

2.5.2 Using the Web in Mathematics Learning

Despite a significant growth in the development and availability of web-based interactive resources for mathematics education in recent years relatively few studies are reported in the literature that focus on the actual use of these web-based resources in teaching and how mathematics teaching, learning and assessment is affected by the use of these web-based resources. In more recent years papers from innovative teachers from both school and higher education sectors have begun to appear in conference proceedings but there is only very limited peer reviewed published work in the public domain. It appears that the higher education sector has made more headway in terms of using the web for mathematics teaching and both undergraduate mathematics subjects and teacher education mathematics programs have been reported to apply web-based technologies in mathematics learning. Some papers from the primary school sector have also reported on the availability and use of web-based resources in teaching of primary school mathematics. This research study found only one project reported in literature where a web-based environment was designed to assist in teaching vocational mathematics (Kavadias, 2003). In the following section I will present a review of selected publications including conference papers and journal articles that relate to teaching of mathematics with the use of web-based learning resources.

Gunnarsson (2001) reported on the development and assessment of a graduate level statistics course taught in an online setting from a private mid-western Jesuit university in the U.S.A. The study involved two groups of forty-two students enrolled in a master in business administration course. One group was taught the subject content using a web-based format and the other group was taught with traditional face-to-face methods. The course covered principles and applications of descriptive and inferential statistics and aimed at making students familiar with basic techniques for understanding, organising, describing and computing research data. The study investigated students' achievement in the course with respect to predictor variables such as their prior computer experience, their prior mathematics knowledge and experience, and their attitude towards the subject of statistics.

In Gunnarsson's (2001) study the online version of the course used a virtual classroom using the Learning Edge option of Lotus Notes computer package. Using this virtual classroom, students accessed all course notes, assignments and PowerPoint presentations for the course. During the course students were given three collaborative group projects using real world data. Students used the online environment to access course content, engage in collaborative group discussions with other students and the teacher, post their assignments and view their course progress. Both the traditional face-to-face class and the online class using the virtual classroom were given the same collaborative projects, homework problems and examinations. In addition, the same teacher taught both classes. This study used questionnaires, individual interviews and an Attitude Towards Statistics test developed by Schau, Dauphinee and Del Vecchio (cited in Gunnarsson, 2001) to collect data and explore any relationship between achievement and predictor variables.

Findings from this study reveal that when the online class was compared to the traditional class the online class had more computer experience and a higher average positive attitude towards statistics than the traditional class. Students' responses on the questionnaire also showed that the majority of them enjoyed online learning, loved the flexibility and did not feel isolated or detached. However there was a small group of students who despite agreeing with the benefits of online learning mentioned that they found it difficult to stay focussed and missed the interaction with other students and the instructor in the face-to-face format. However, in terms of achievement both groups produced comparable results and there was no clear advantage or disadvantage of using the virtual classroom in their final results.

Although this study was able to show clearly that students' attitude towards statistics is positively affected by the use of an online learning format, it appears to have focussed only on the flexibility of access and collaborative communication aspects of the web-based environment. It did not appear to use any interactive online mathematics learning objects or tools to enhance students' knowledge and skills of mathematics. In addition, the study also reported that some students did not favour a fully online course in mathematics and, while acknowledging the advantages of online learning, indicated their preference for face-to-face contact with their peers and the teacher. The study shows that blending face-to-face learning with an online learning environment has the potential of meeting most students' learning needs while utilising the web technology for enhanced learning opportunities.

Engelbrecht and Harding (2004) reported on the use of web-based teaching of first year calculus courses in an undergraduate course from the University of Pretoria, South Africa. In this study the authors taught first and second semester calculus courses in a web-based mode where face-to-face contact was limited to one hour per week in a discussion mode. The course materials were provided via WebCT and a course book and students used email and a discussion forum to communicate during the course. The authors discuss the merits of combining online and paper-based assessment models and provide an analysis of results comparing students' performance in both forms of testing. Student surveys are used to establish their preference for assessment.

The authors used a combination of online and paper-based activities for both formative and summative assessments during this course. As part of formative assessment weekly online quizzes were done that provided instant feedback and results. In addition students were also required to do four hard copy assignments and a project activity for the course. The project required the use of Maple or Matlab software. The online quizzes consisted of Multiple Choice Questions (MCQ) and Constructed Response Questions (CRQ) but assignments consisted of CRQs only. During marking of tests while students were able to gain partial credits for their working out in CRQ type questions, no partial credit was possible with MCQ type questions where they were marked as either correct or incorrect. The final examination for the course also included both online and paper based components and equal credits were awarded to each component of the test.

While online assessment through quizzes focused on testing core mathematical skills and concept understanding using MCQs, the paper based assessment dealt with calculations or manipulations ranging over a number of steps. The results from the study comparing the performance in paper sections of tests with the online sections over a period of four semesters reported no “disturbing” difference between the online and paper sections (p. 228). Although performance in online tests appeared to be slightly better than paper based tests the difference decreased gradually over four semesters indicating that mastery of writing MCQs improves over time. The Pearson correlation coefficient between performances of individual students in the online and paper section of all tests changed from values of 0.10 and 0.13 in the first two semesters of testing to values of 0.58 and 0.35 in the last two semesters of testing indicating that the consistency between online and paper based results improved over time.

Survey results from this study also point to students’ overwhelming preference for combining online testing with paper based testing, with more than 75% students preferring to allocate 50 to 70 percent credit to online assessment. Only 8.7% students said that no paper-based tests should be done. The main reasons for the preference of including online tests were that they provided immediate feedback and students could see if they needed to work more on the topic, offered flexibility in terms of when and where the test was taken and exposed them to use of computers in learning mathematics. The main reason given for preference for paper-based tests was the availability of partial credits.

The study clearly points towards students’ willingness to have a component of assessment in the online mode. In addition the study also shows that the quality of assessment does not deteriorate in the online mode although paper-based assessment in mathematics is able to assess skills such as formulation, exposition and sketching which are difficult to assess in the online mode.

In another study from the higher education sector Martinez, Barcena and Rodriguez (2005) designed a web-based learning resource to help in teaching of geometry proof in a undergraduate course in Spain. Using CabriWeb feature of the Cabri-Geometre software the authors designed dynamic geometry objects that could be explored using a java compatible browser on the web. The Cabri-Géomètre software allows construction of geometrical figures that can be used for teaching and learning geometry. One of the key features of this dynamic construction is that the user continuously sees the figure redrawn in real time keeping all its initial properties. In this way Cabri lets the user conceptualize a figure not as a static drawing but as a set of objects linked by geometrical relationships (Martinez, Barcena, & Rodriguez, 2005).

The design of the learning environment used Java sketches to help students learn to develop problem-solving strategies and procedures and to apply them during problem solving. As an example, the study reports that classroom problems were chosen to highlight some properties of triangles and related tasks were designed to encourage students to search for explanations with regard to the relationships that come across through the observation in the sketch. The tasks also assisted students in moving through exploration, prompting them to examine the evidence in the sketch and check the hint and the goals in the proof-problems. In this way the sequence of activities the authors used instructed students to discover unaided ideas for visual proofs that can be extended to pure mathematical proof. The authors report that the utilization of Java applets has allowed them to use the time previously spent on constructing the figures in traditional methods for inquiry, in carrying out an investigation, discovering properties and geometric relations which promotes their geometric intuition.

Consistent with the notion of “using before knowing” (Noss & Hoyles, 1987, p. 29) which assumes that understanding emerges through activity, the study by Martinez, Barcena and Rodriguez (2005) encouraged students to discover unaided ideas for visual proofs and then extend this understanding to learning pure mathematical proofs.

In a study of using the Internet with mathematics teaching in teacher education courses in Brazil, Borba (2005) investigated the issue of how mathematical knowledge is modified by the use of technologies and the Internet chat. His study was based on the premise that knowledge is always constructed by collectives that involve humans and different technologies, and the interaction between technologies and humans has the potential to transform the knowledge that is produced (Noss & Hoyles, 1997; Borba, 2005).

Borba (2005) noted that researching how collectives of humans-with-the Internet have constructed knowledge also transforms methodologies of research because data collection is more ‘natural’ in the Internet based educational environments when compared with face-to-face teaching. In the Internet environment recording of data such as chat and email exchanges is automatic and issues of intrusiveness faced in traditional face-to-face research methods are not of concern.

He reported use of online chat for two courses namely – ‘Trends in Mathematics Education’ and ‘Teaching and Learning Geometry using software’. In each course about 20 teachers who were dispersed geographically in remote areas of Brazil participated in weekly chat sessions for a period of about four months. The courses also used bulletin board and email messages to keep contact and support learning sessions via chat. It is important to note that Borba’s research is based on an experience of five years of using the chat sessions with these courses and it is not surprising that the success of online chat sessions followed careful planning where reading material or mathematical tasks were posted to students in advance and they were expected to have completed them before the chat session. In addition, the researcher and two nominated students from the class were given the role of raising questions in the chat sessions to generate discussion. A third nominated teacher was given the responsibility of summarising the chat session and posting it on the virtual environment for the course.

Borba reported that Internet-based chat sessions generated mathematics which would be not possible in face-to-face teaching sessions. For example he notes that while students using graphing calculators to generate conjectures for the problems related to coefficients of parabola would not be writing their explanations in a face-to-face class, in an online learning environment based on chat, writing is natural and doing mathematics in this online environment has the potential to change the mathematics produced because “writing in non-mathematical language becomes a part of doing mathematics” (p. 175).

The research by Borba showed that online chat can be successful when students are engaged in a carefully planned and executed program that provides adequate scaffolding for students’ participation in online chat sessions. Research by Smith and Ferguson (2005) has however shown that in American distance education programs in general there is much less success in teaching mathematics by use of Internet-based synchronous and asynchronous means. Their research showed that lack of support for communicating mathematics symbols and expressions in the online medium plays a detrimental role. They argued that doing mathematics involves problem solving situations and discussion threads and chat sessions are not very successful with problem solving aspects of mathematics. Their findings have shown that there is a greater attrition of students from online mathematics courses in distance education compared with non-mathematics courses.

Although Borba did not mention the issue of difficulties of expressing mathematics in the online medium, especially in chat sessions, it is clear that Borba’s focus of chat sessions for mathematics course was on discussing mathematics solutions rather than solving problems. It appears that teacher education and professional development courses where teachers are expected to discuss mathematics in addition to gaining skills and knowledge of solving mathematics problems, online chat has a legitimate role to play and could add a new dimension to mathematical knowledge as suggested by Borba.

In a study from a teacher education program from Canada where pre-service mathematics teachers were being encouraged to use Internet-based Java applets in their lessons Gadanidis, Gadanidis and Schindler (2005) reported on the pedagogical thinking of teachers in using online applets in their lesson planning. The application of new media in this study was influenced by the thinking that mathematics teaching needs to find a pedagogical balance between listening to teacher exposition and practicing procedures with active investigation of mathematical relationships (Gadanidis, Gadanidis, & Schindler, 2003). The authors noted that new media not only enable us to express our ideas in new ways – they also affect the ideas we have: “We don’t always have ideas and then express them in the medium. We have ideas with the medium” (DiSessa cited in Gadanidis, Gadanidis, & Schindler, 2003, p. 326).

The authors offered two sets of Java applet programs to teach the topics of graphing linear equations and determining experimental and theoretical probability when rolling one die or two dice. The Java applets offered simulated rolling of one or two dice with records of results and interactive graphing of a linear function of the form $y=mx + b$ and $y-y_1 = m(x-x_1)$. The pre-service students were shown the working of these applets and were given access to these applets to explore their function and use in teaching of relevant mathematics topic. Students were then asked to make lesson plans for teaching the two mathematics topics and were asked to consider all available resources for teaching the topics. They were given the choice to use or not use the applets in their lesson plans. The lesson plans created by these pre-service students were analysed to explore their pedagogical thinking in hypothetical lesson planning situations.

Observations from the study suggested no consistent pattern in the use of applets in lesson planning during the study. Pedagogical beliefs of pre-service teachers reflected in their lesson plans showed that some believed in the need for teachers to first teach key concepts but others believed that students needed to first investigate mathematical relationships. In addition, the mathematics topic to be taught also influenced the nature of lesson plans, for example they found that a topic like linear functions was more likely to be treated in a traditional teacher-centred way but a topic like probability was more likely to involve student investigation.

In one more study from the teacher education sector Li (2003) reported on the use of discussion forums in teaching a graduate course in mathematics for elementary schools in a Canadian university. The course involved regular face-to-face contact and participation in asynchronous computer conferencing. Ten student teachers participated in a semester long study.

Although the study did not provide data on the level of engagement by participants in the discussion forum it suggested that the forums provided a successful and novel experience to both the author and student teachers doing this course. The author noted that the use of discussion forum provides a more comfortable environment than face-to-face settings to discuss sensitive issues. The author also noted that "teachers (student teachers) talked frankly in threaded discussions about prickly and uncomfortable topics underlying education that I have never seen in their face-to-face engagements" (p. 76). Li (2003) also pointed out that threaded discussion also offered more choices by allowing students to choose the topic to which they wish to respond or create a new topic. In addition, Li (2003) noticed that discussions on the Internet forum became a reading and writing task as writing a comment took more time than saying it in an oral conversation because most people liked to edit their messages before posting. The author confirmed that more research was needed about understanding how students learn using the Internet.

Patahuddin and Dole (2006) reported on the use of Internet in an ethnographic study from a primary school in Queensland. In this study a teacher from a senior primary grade used the Internet to support and extend classroom based mathematics learning. The study explored the use of the Internet by the teacher in teaching of mathematics and what impact it had on students' learning. The classroom where this study was conducted consisted of 26 students and six computers with only two of them connected to Internet. The teacher used the Internet connected computers strategically to engage students in mathematics research, to access learning objects and manipulatives, explore investigations, compare and communicate ideas with others, play maths games and solve maths puzzles.

The study noted three main reasons for the teacher's use of the Internet in her class, namely "(1) to achieve her mathematics teaching objectives that mathematics is everywhere, (2) to facilitate student learning and (3) to have a good understanding and skill in using ICT" (p.404). The teacher reported that the use of the Internet impacted positively upon students' learning. They were more engaged with learning demonstrated by their being more active in asking questions and discussing ideas. Students also collaborated with others and those with extra needs had the opportunity to extend or support their maths learning. The study also reported that initiatives to use the Internet in learning sometimes came from students and the availability of the Internet affected the teacher and made her role more of a facilitator of learning and through the Internet she was able to find the means to more easily engage students in learning and to cater to the various needs of different students. The study showed that the teacher’s skills and knowledge of computer and the Internet positively affected her success in integrating Internet based activities in her mathematics lessons. She was able to research and bookmark useful and relevant websites for easy access during the class time and had done her preparation for creating learning tasks that effectively guided the students to make use of the learning resources available on the Internet.

Ng and Hu (2006), in a study from a Singapore secondary school involving a group of gifted year 9 students, reported on teaching the topic of trigonometric curves using an interactive web-based simulation and following it with an online asynchronous discussion. During the study students worked in groups of three or four in experimenting with the web-based simulation to learn to sketch dilations and translations on trigonometric curves. The online discussion forum in the study was designed to help students decipher the concept behind each transformation using written dialogue and discussion.

The students first learned the concepts related to trigonometric curves during a 70-minute lesson where they completed four online activities on the topic with the help of the simulation Trigonometric Graph. In the following session they learned how to sketch transformations using Trigonometric Graph and took a 5-item paper-based quiz to test their knowledge. These two sessions were followed by four days of online discussions on the topic, concluding with an oral examination at the end of a seven-day period.

Findings from the study indicated that the pass rate on the paper-based quiz was higher for this group compared to two previous classes who had received only traditional teacher-centred instruction and did not use web-based simulation activities. The authors reported that only 33% of students from this experimental group managed to sketch horizontal translation in the paper-based quiz, which was drastically lower than was found in the similar tasks in the online activity (79%). Similarly, only 41% could sketch combinations of transformation in the paper-based quiz whereas 79% of them were able to do a similar task in online activity (p. 7).

The authors reported a positive impact of the use of the discussion forum because it allowed opportunities for students to reflect on their learning and also some students who otherwise would not take part in discussion were able to contribute via the discussion forum. The authors noted that although the results of the study suggested that students' performance improved by using web-based simulations in learning trigonometric curves as shown by overall quiz and oral examination results, the anomaly presented by much higher success in online activity questions compared with paper-based quiz questions suggests that because concept based simulations are designed to explain a phenomenon they may help students understand why something is happening and not how. They argue that the key to concept-based simulations is to ask students to explain "why" but not "how" questions (Ng & Hu, 2006, p. 9).

The study showed that use of web-based simulations and discussion is able to create opportunities for more constructivist learning in mathematics and reduce teachers' dependence on expository methods. But more research is needed to establish how to assess and account for learning that is facilitated by new technological tools.

Khalid (2004) reported on a study in a technical college in Brunei where she taught mathematics to diploma in electrical engineering students using an innovative package. Although Khalid's study did not make explicit use of web-based mathematics learning her package included activities where students had to use the Internet to explore and research particular concepts. Using lessons that emphasized an intuitive rather than rigorous instructional approach she adapted authentic real world and work contexts in her teaching. Her mathematics lessons on the topic of trigonometry for technical students included cooperative learning tasks and an integration of academic and technical subjects. The purpose of Khalid's study (2004) was to look at the impact of changing the classroom environment in terms of instructional and pedagogical context on the attitude and mathematics achievement of students.

Participants of this study comprised two classes of students in their first year of National Diploma in Electrical and Electronics Engineering and National Diploma in Radio, Television and Electronics Engineering. These two classes were taught using a package on the topic of Trigonometry, designed and developed by the researcher. Using a mix of qualitative and quantitative measures cognitive and affective achievements of students were compared by pre-test and post-test for achievement; enjoyment and interest, and relevance and importance scales for attitude and a classroom environment survey. In addition classroom observations and student interviews were also conducted.

Findings from this study showed that one class had a statistically significant increase in pre-post test scores in cognitive achievement ($t(11)= 5.59$, $p<.001$) whereas the other class showed only a marginal increase ($t(9) = 0.76$, $p<0.01$). But, because the post test was conducted after a number of weeks of instruction, it is naturally expected that students would show a better cognitive performance in post tests in comparison with their pre test performance. Results from pre-post attitude scores comparison indicated that while students' mean score for interest and enjoyment scale increased, there was a significant drop in the scores for the relevance and importance scale. The author reported that not all students preferred the innovative teaching methods such as cooperative learning and problem solving and a small number of mature aged students with experience from the industry considered the new approach as a "waste of time". The study reported that mature students who were comfortable with the traditional way of teaching seemed to resist changes. This study by Khalid (2004) highlights the problems associated with implementing instructional changes in a technical and vocational education setting and the difficulties in achieving empirical evidence for the effectiveness of intervention and innovation in mathematics teaching.

This section has presented a review of studies where web-based learning was used in teaching of mathematics. While Gunnarsson's (2001) study showed that students favoured a blended approach to learning rather than a fully online mode, Engelbrecht and Harding (2004) were able to show that students preferred to have a component of their assessment in the online mode and that the quality of assessment does not deteriorate in the online mode. Noting the challenges of designing appropriate assessments for web-based mathematics learning Ng and Hu (2006) note that simulations on the computer help students understand why something is happening and in assessing students understanding of mathematics it is more important to ask students to explain the “why” rather than “how” questions. In addition, studies of Java based simulations in mathematics classes have also shown that the utilization of Java applets allows students to use the time previously spent on constructing figures using pen and paper on computer based investigations and discovery of properties and geometric relations which promotes their geometric intuition (Martinez, Barcena, & Rodriguez, 2005). Studies from the use of web technologies in mathematics learning for teacher education courses (Borba, 2005) point to the usefulness of web chat technologies in discussing mathematics learning issues by prospective teachers. The research shows that writing in mathematics chat sessions produces a kind of mathematics not possible in face-to-face classroom sessions. Studies reported in this section also illustrate the orchestration (Hoyles, Noss & Kent, 2004) and how a learning environment is influenced by teachers’ instructional beliefs. Gadanidis, Gadanidis & Schindler (2005) found that while using online applets in their lesson planning some teachers’ preferred to teach the concept first, others allowed students to explore the online applets to develop their conceptual understanding. These studies show an emerging field of web-based mathematics learning in both school and higher education sectors and demonstrate that while designing an appropriate online learning environment is very important issues of appropriated blending of face-to-face learning with online learning and assessment practices that take into account the affordances of online learning are equally important.

2.6 Conclusion

This chapter has presented a review of mathematics teaching and learning in the context of new learning technologies to illustrate how these new technologies offer an enormous potential to influence and transform mathematics learning for vocational education. The influence of new technologies in modern workplaces has increased the need for techno-mathematical literacies in workers and this literature review has shown that mathematics teaching in vocational education and training would potentially benefit from appropriate use of a technology enriched learning environment in mathematics teaching. In this research project the design and development of a web-based learning environment was influenced by this desire to enhance and transform mathematics learning for the vocational education students.

This literature review has also shown that although considerable research and development has taken place in recent years in terms of developing web-based interactive systems to teach mathematics in a range of contexts, the teaching of mathematics for vocational education has remained relatively un-researched (FitzSimons, 2002a). This review found only one more web-based learning environment (Kavadias, 2003) focusing on the teaching of mathematics in vocational area. The review has also shown that second order factors (Ertmer, Addison, Lane, Ross, & Woods, 1999) play an important role in the success of technology use in classroom teaching and the teachers' skills, motivation and a close involvement in design and implementation of technology play a crucial role in its effective use in the classroom. Using a design-based research methodology allowed this research to be closely linked to the practice of TAFE teachers of mathematics and helped in exploring and analyzing the role of the teacher in technology enriched mathematics learning.

Developments in web-based learning technologies appear to have reduced the technological impediments in displaying and communicating mathematics on the web and research developments such as Web-based Mathematics Education systems offer greater control and interactivity to mathematics teachers for designing web-based learning environments. The review of classroom research studies from higher education and school sectors pointed to the need for studies that not only attempt to test the effect of technology use on achievement and attitude by quasi-experimental comparison but also to explore students' interaction with and use of these online learning environments in mathematics to determine factors that influence their participation and learning. As a result the current study focuses not only on the design and development of a web-based learning environment for mathematics but also on exploring its use by mathematics teachers and students over a period of two research cycles as described in the next chapter on methodology.

Chapter 3: Methodology

3.1 Introduction

This research aimed at achieving two things: firstly, at the design level its main objective was the development and refinement of a web-based mathematics learning environment to support and enhance classroom based teaching of vocational mathematics and secondly, at the practice level, its main aim was to conduct a systematic study to understand how students learn with the help of this new learning environment, what factors affect their use and participation and if it leads to any comparable differences in their attitude towards mathematics and performance in course assessments. The research process was also designed to serve as a catalyst for increasing acceptability of web-based learning in classroom practice. Section 3.2 of this chapter presents an overview of positivism, constructivism and pragmatism as three research paradigms and argues that pragmatism provides a sound epistemological base for a practical and outcome-oriented method of enquiry applied in this research. In Section 3.3 the methodological framework for design-based research methodology is discussed in detail and connections between methods used in this research and the design-based research methodology are established. Sections 3.4 and 3.5 provide details of the two research cycles in terms of design, enactment and analysis involved in each research cycle. Section 3.6 of this chapter presents the quality, trustworthiness and alignment criteria and how these are addressed in this study. The chapter concludes with Section 3.7 where summary of this chapter on methodology is presented.

Hsi (1998) notes that studies involving technological innovation in classroom practice require a new methodological approach. He insists that new models of research that engage teachers as co-investigators and forge strong teacher-researcher collaboration are needed. Brown (1992) also claims that the criteria for measuring learning success such as skill acquisition or criterion measures on tests or inventories commonly used in the psychology tradition as a single measure are inappropriate and weak for advancing our understanding of how to design for change in educational settings. Ramage (2001) in his literature review of the “no significant difference” phenomenon points out that “selection of the media has little to do with learner outcomes, rather the method that the media share in delivering content is the true catalyst that leads to understanding” (No page no.). He identified that in most studies the difference shown in the outcomes was due to method factors rather than media. He also confirmed that many attributes and variables present in an educational context could not be systematically studied by a pure scientific method. A new approach to research that leads us to a holistic understanding of the process and impact of a technological innovation on classroom practice and student learning may be provided by a mixed method methodology that employs both qualitative and quantitative measures and works within the framework of teachers as co-investigators.

The methodology for this research has been influenced by the ‘action research’ and ‘design-based research’ approaches. Action research as a methodology offers opportunities for teachers to act as researchers and reflect on their practice. Another element of action research is the spiral of planning–acting–reviewing and evaluating, which allows teacher-researchers to refine practice constantly (Carr & Kemmis, 1986; McTaggart, 1991). Both elements of teacher as a researcher and the cyclic process of intervention were present in this study. However, action research is historically located in the tradition of social change and views use of empirical methods less favourably. It places a higher priority on reflection and action. On the other hand, design-based research as a methodology shows several commonalities with action research but advocates a more systematic study process. Design research methodology is concerned with both the development of learning environments and a systematic study of forms of learning generated in these learning environments (Brown 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). It also entails a continuous process of testing and revision to refine the designed learning environment. Design based research methods use both qualitative and quantitative methods and are suited to studies of technological intervention. These methods have been applied successfully in research studies in the field of science and mathematics education (Hoadley, 2004).

This research study comprised two stages or cycles. In the first cycle collaboration between two mathematics teachers and the teacher/designer/researcher led to the development of a web-based learning environment. Its design and learning content were evaluated using a systematic implementation strategy. Feedback from this cycle was incorporated in the design using a continuous editing and revision process. During this cycle student and teacher questionnaires were also used to seek formal feedback. In addition, informal feedback was gained via classroom interaction with learners and discussions with collaborating teachers. Findings from this first cycle led to the second cycle of design and research.

The second cycle comprised another iterative process of design, enactment, analysis and review. During this cycle qualitative measures of participant observation and interviews were used to gain a deeper understanding of the factors affecting the design and effectiveness of the planned innovation. Along with the design and qualitative measures another strand of enquiry was added to research. In this strand a quasi-experimental study was also included to compare the attitude and performance of students who used the online environment with those students who did not use the online environment.

Following a mixed method approach embedded in the design-based research methodology this research has attempted to use appropriate qualitative and quantitative measures to complement findings and draw meaningful conclusions.

3.2 Research Framework

Researchers in the field of education have several methodological choices at their disposal to construe their research. Arguably, researchers with a leaning towards objectivist epistemology tend to favour quantitative research methods whereas researchers with a constructivist epistemological disposition lean towards qualitative research methods (Bogdan & Biklen, 1998; Borg & Gall, 1989; Denzin & Lincoln, 2000; Johnson & Christensen, 2004). For a long time research purists have maintained that that these two epistemological positions are mutually exclusive and researchers should avoid mixing them in their research. Another research paradigm based on pragmatic ideology is concerned with practical consequences of intervention and promotes mixed method research methods (Tashakkori & Teddlie, 2003). The following sections expand on these three paradigms (Table 3.1) and show how a pragmatic paradigm with mixed research methods embedded in design experiment methodology suits the research questions being investigated under this study.

3.2.1 Positivism

The paradigm associated with the objectivist epistemology is commonly known as positivism. Guba and Lincoln (1994) have defined paradigms as worldviews or belief systems that guide researchers. The term paradigm was first coined by Kuhn (1970) in his title *The Structure of the Scientific Revolutions* in which he challenged the legitimacy of assumptions underlying the traditional scientific method. Borg and Gall (1989, p. 17) describe positivism as “a system of philosophy that excludes everything from its consideration except natural phenomenon and their interrelationships.” Positivism defines knowledge solely on observable facts and does not give any credence to non-observable entities such as feelings and values.

Table 3.1
Comparison of important paradigms

Paradigm	Positivism/ Post-positivism	Pragmatism	Constructivism
Methods	Primarily Quantitative	Quantitative + Qualitative	Qualitative
Logic	Primarily Deductive	Deductive + Inductive	Inductive
Epistemology	Objective Findings probably objectively “true”	Both objective and subjective points of view	Subjective point of view. Knower and known are inseparable.
Axiology	Inquiry is value-free or values can be controlled	Values play a large part in interpreting results	Inquiry is value bound
Ontology	Naïve realism/critical or transcendental realism	Accept external reality. Choose explanations that best produce desired outcomes	Relativism

Adapted from Tashakkori and Teddlie, 1998

Lincoln and Guba (1985) outline the main features of positivism and illustrate that in terms of ontology (nature of reality) positivists believe that there is a single reality and that this reality is apprehendable. Pointing out that the tradition of science is based on the notions of positivism Crotty (1998) notes that:

> *Whereas people ascribe subjective meanings to objects in their world, science really 'ascribes' no meanings at all. Instead, it discovers meaning, for it is able to grasp objective meaning, that is, meaning already inherent in the objects it considers. To say that objects have such meaning is, of course, to embrace the epistemology of objectivism. Positivism is objectivist through and through. (Crotty, 1998, p. 27)*

Positivism also asserts that the knower and the known are independent and that the research enquiry is value free. Positivists hold the view that by using the scientific methods correctly one can make unbiased and objective observations (Borg & Gall, 1989) and that the results obtained through these methods may lead the researcher to draw time and context free generalisations (Guba & Lincoln, 1994). They also claim that their methods lead them to establish valid and reliable cause and effect relationships (Johnson & Onwuegbuzie, 2004). Positivism espouses the view that "entities of one kind...are reducible to entities of another," such as societies to numbers, or mental events to chemical events and "processes are reducible to physiological, physical or chemical events" (Trombley, Bullock, & Lawrie, 1999, p. 673).

Positivism is closely tied to quantitiative methodologies and experimental methods of data collection and analysis. Although positivism has served the world of physical sciences well and has remained dominant as a research paradigm there, in social and behavioural sciences it has come under sharp criticism from researchers. Critics of positivism claim that observations are always theory laden and there is no such thing as value-free, objective and neutral observation to test a hypothesis (Bogdan & Biklen, 1998; Carr & Kemmis, 1986).

Another assumption of positivism that has been criticised by qualitiative researchers is its insistance that the testing of knowledge claims should be restricted to conditions that are observable (Borg & Gall, 1989). It means that in educational and social science research we are restricted to studies of observable behaviours such as test performances and responses to paper and pencil questionnaires that can be observed and scored objectively. Positivism does not offer any tools to researchers who are interested in the study of feelings, intentions and social dynamics of classroom learning. Borg and Gall (1989) contend that there is no convincing reason to believe that observable behaviour is more real than internal phenomena such as feelings and intention.

The research orientation adopted in this study does not subscribe to the positivist epistemology. The study is aiming to research the practice of introducing a technological innovation in the classroom practice of teaching and learning mathematics and aims to explore both the qualitative aspects in terms of students' feelings and behaviour in adapting new technologies in their learning as well quantitative aspects in terms of their attitude towards mathematics and performance in tests.

Discontent with the axioms of positivism led to the emergence of post-positivism as a new paradigm in the post 2^{nd} world war era (Borg & Gall, 1989; Crotty, 1998; Guba & Lincoln, 1994; Johnson & Onwuegbuzie, 2004). Post-positivism contends that there is a real and objective reality but it acknowledges that this reality is only imperfectly and probabilistically apprehendable. Lincoln and Guba (2000, p. 165) refer to this as "critical realism" in contrast with positivism's "naïve realism". Denzin and Lincoln (2000, p. 9) point out that "post-positivism relies on multiple methods to capture as much of reality as possible". Thus post-positivism accepts the theory-ladenness and value-ladenness of observation and agrees that "it is possible to acquire knowledge about a phenomenon not directly observable by the senses" (Borg & Gall, 1989, p. 21).

Although post-positivism as a paradigm offers a range of methodological choices and researchers could employ multiple methods including qualitative measures, it still contends that the reality is independent of the observer and the methods used to produce it. Positivist and post-positivist paradigms do not promote collaborative or participatory research where research is oriented towards bringing about change. The current study is participatory in the sense that I, as a researcher, was also a co-worker and participant in the design and implementation of the learning environment being researched.

3.2.2 Constructivism

Constructivism emerged as an alternative to the positivist paradigm for social and educational enquiry. Constructivism shares common beliefs and goals with naturalism or interpretivism. Lincoln and Guba (2000) point out the sharp ontological and epistemological contrast between positivist and constructivist paradigms. They note that the constructivists believe in relativism and that there are local and specific constructed realities. Constructivists follow a subjectivist epistemology signifying that the knower and respondent co-create understandings. They also believe that that there is no objective reality; rather it is constructed by individual and collective experience. Radical constructivists believe that knowledge is first constructed internally then externalised, whereas social constructivists believe that knowledge is first external and then internalised (Lesh & Doerr, 2003). A leading proponent of radical constructivism von Glasersfeld (quoted in Steffe & Wood, 1990, p. 37) notes that "knowledge is the result of an individual subject's constructive activity, not a commodity that somehow resides outside the knower and can be conveyed or instilled by diligent perception or linguistic communication". The radical constructivist philosophy discards the traditional position of realism according to which "knowledge has to be a representation of an essential reality, i.e., an 'out there' world prior to having been experienced" (Boudourides, 1998). On the contrary, it adopts a relativist position that knowledge is something that is personally constructed by individuals in an active way, as they try to give meaning to socially accepted and shared notions.

Vygotsky's (1986) theories about language, thought and their mediation by society are relevant to the ideas of social constructivism. He formulates an anti-realist position that learning could not be based on a direct association and argues that the process of knowing is rather a disjunctive one involving the agency of other people and mediated by community and culture (Boudourides, 1998). Crotty (1998, p. 57) prefers to use the label of 'constructionism' for social construction of knowledge from external to internal. Schwand (quoted in Crotty, 1998, p. 57) adds that constructivists “emphasise the instrumental and practical function of theory construction and knowing”.

Crotty (1998) argues that social constructionism tends to foster the critical spirit of inquiry whereas constructivism tends to resist it. He suggests that constructivism “points up the unique experience of each of us” in such as way as to suggest that “each one’s way of making sense of the world is as valid and worthy of respect as any other, thereby tending to scotch any hint of a critical spirit ” (Crotty, 1998, p. 58). In contrast, social constructionism focuses on “the hold our culture has on us” in shaping our experience and the way we see things to give us a definite view of the world (Crotty, 1998, p. 58). Constructionists acknowledge the inevitability of experience being shaped by culture but hold that it is both a limiting and liberating factor, and must be called into question. Critical social science embraces this epistemological position of social constructionism to embark upon a democratic theory of political action (Carr & Kemmis, 1986).

Whereas constructivism assumes the relativism of multiple social realities, recognises the mutual creation of knowledge by the viewer and the viewed and aims towards interpretive understanding of subjects’ meanings it also shows two divergent views on construction of knowledge. Crotty (1998) refers to one as being influenced by the pragmatic thinking of George Herbert Mead (1863-1931) and describes it as one constructed by radical constructivists and symbolic interactionalists as “a peaceable and certainly growthful world” (Crotty, 1998, p. 62). It is a world of intersubjectivity, interaction, community and communication where construction of ideas occurs in a discourse building upon our previous understanding. In contrast, it is the world of social constructivism where critical theorists deal with a world of “striking disparities in the distribution of power”. They deal with a world full of inequities and injustices “torn apart by dynamics of oppression, manipulation and coercion” (Crotty, 1998, p. 63). Crotty (1998) argues that research methodologies adapted by these two divergent constructivist viewpoints would need to be very different and would serve very different purposes.

Commenting on the nature of constructed knowledge in the discipline of mathematics Lesh and Doerr (2003) points out that significant portions of knowledge in mathematics that students need to learn are not “constructs”. They argue that skills and procedures are not concepts in the sense of conceptual systems and hence they do not need to be constructed. They contend that students would need to acquire proficiency in these skills and procedures in order to use them in construction (or reorganising or refining or testing) of more complex conceptual systems. Piaget (quoted in Lesh & Doerr, 2003, p. 215) also admits that construction is only one of many relevant processes to knowledge development and knowledge is sorted, refined, modified, integrated, and extended, as well as constructed from existing knowledge (Phillips, 2000).

Constructivism has influenced my work as a teacher and during this research the planned intervention draws on ideas proposed by constructivism (Glasersfeld, 1995, 2002) and ‘anchored instruction’ (CTGV, 1992). However, the teaching and research methods employed in this study also include use of technology resources for skills acquisition and use of empirical methods to collect information about students’ attitudes and achievements.

3.2.3 Pragmatism

Located between the ‘paradigm wars’ of an objective positivist epistemology and a subjective constructivist epistemology, pragmatism offers an “immediate and useful middle position both philosophically and methodologically” (Johnson & Onwuegbuzie, 2004, p. 17). Pragmatism emerged as a philosophical movement in the latter part of the 19th century mainly through the works of Charles Peirce (1839-1914), John Dewey (1859-1952) and others who agreed in their rejection of positivist assumptions about the nature of knowledge and truth, and presented a “sympathetic challenge” to the notion that the application of a single method of inquiry namely, the scientific method, would enable us to access the “real world” (Maxcy, 2003, p. 52).

According to Dewey a pragmatist’s conduct of enquiry does not need to be a “quest for certainty” or rely on certain “foundations” of knowledge. He believed that there is an intrinsic connection between the meaning and action and asserted that a method of pragmatic enquiry included three things: “(a) the fact of primary or “had” experience is wider and deeper than the cognitive reflection; (b) the fact that all experiences grow out of transactions; and (c) the notion that the forms, structures, frameworks, paradigms, networks and so on are realised out of inquiry and not merely discovered" (Boisvert, 1988, p. 206 quoted in Maxcy, 2003, p. 57). Dewey's emphasis on the experiences growing out of "transactions" and the notion of "inquiry" bear a particular resonance with the epistemological position and methodology adopted in this research.

Dewey's pragmatism explained the acquisition of knowledge as both an inductive and deductive process. He argued that knowledge in some forms exists as "reality" and in other forms the "knower" constructs it (Maxcy, 2003, p. 72). He believed in a naturalised scientific method and argued that, "science becomes understandable only if we drop the conception of science as a system of absolute truths" (Maxcy, 2003, p. 72). As a result pragmatic methodology was able to break away from the rigid structures of traditional educational and social science research and propose mixed methods where qualitative and quantitative methods could coexist to inform research (Johnson & Onwuegbuzie, 2004).

In terms of subjectivity and identity in research, a pragmatist believes in "practical intersubjectivity" where the only significant criterion for identity in meaning is in the agreement in action (Biesta, 1994 quoted in Maxcy, 2003, p. 62). Pragmatism rejects traditional dualisms such as subjectivism vs. objectivism and rationalism vs. empiricism and advocates a common sense approach in which relative significance of a philosophical stance is determined by how well it works in solving given problems. In place of the traditional dualism Dewey's constructive pragmatism, which is adapted in this study, promotes a meaning–action connection. Vanderstraeter and Biesta (quoted in Maxcy, 2003) expanded on Dewey's position to note that "It is through social transactions that we come to understand the existence of multiple subjective realities while at the same time seeking agreement via action" (p.59). It is clear that pragmatism differs from positivist notions of objectivity and endorses collaborative action while acknowledging participants' subjective realities. Maxcy points out that, "Given this view of Dewey as a constructivist, we may see that mixed methods of social science research are warranted by a Deweyan pragmatism" (p.59).

Pragmatism has been often criticised from two simplistic notions of “naïve realism” and “radical relativism”. Pragmatists are frequently criticised for their short-sighted practical approach that does not show any consideration for ideals and values. In addition, pragmatists are also attacked from others for their disposition for an uncritical exploration of cultural ideas and values in terms of their practical outcomes (Crotty, 1998). Transformative-Emancipatory research proponents often claim that pragmatic research fails to articulate values and interests of people who are likely to gain from the practical outcomes of inquiry (J. A. Maxwell & Loomis, 2003).

In educational research pragmatism provides a sound epistemological base and offers an immediate and useful middle position philosophically and methodologically (Tashakkori & Teddlie, 1998). Johnson and Onwuegbuzie (2004) assert that pragmatism offers a “practical and outcome-oriented method of inquiry that is based on action and leads, iteratively, to further action and the elimination of doubt” (p. 17). Additionally, in terms of answering research questions, pragmatism allows methodological mixes that can help researchers answer these questions in a better way.

Both action research and design-based research methodologies are principally grounded in the pragmatic epistemology and share common threads (Carr & Kemmis, 1986; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Firstly, both research methodologies are naturalistic in the sense that they are concerned with action and reflection occurring in the real or authentic context or setting. Secondly, both research methodologies are participatory in the sense that the researcher is actively involved in the process of action or change. Thirdly, there is an iterative process involved in both research methodologies where there is a continuous cycle of planning, action and reflection. However important distinctions exist between these two methodologies; while action research is epistemologically closer to critical theory and places a greater emphasis of social action and change, design research is closer to post-positivist epistemology with an emphasis on empirical evidence in evaluating an intervention. Furthermore, action research is based on active participation of all involved and is oriented towards collective action and social change; whereas design research is concerned with active participation and collaboration for the purpose of extending our knowledge about innovative learning environments. It is this emphasis on designing an innovative learning environment and using mixed methods to inform findings that influenced the design of this study and the subsequent use of the design-based research methodology.

3.3 Methodological Framework

Design-based research is an emergent methodology and has its roots in the field of educational psychology. Brown (1992) and Collins (1992) proposed this methodology with the coining of the term "design experiments" for studies of classroom-based interventions where the purpose of the research was to actively participate in the design and implementation of an innovation in order to test and develop theories of instruction. Design-based research is concerned with both design of a learning environment and a systematic study of this designed learning environment in a natural setting.

The Design-Based Research Collective (2003) postulates five characteristics of design-based research:

- The goal of designing learning environments and the goal of developing "conjectures" (Sandoval, 2004, p. 214), theories or "prototheories" are closely linked.
- The development of research takes place through continuous cycles of design, enactment, analysis and redesign (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Collins, 1992).
- Research on design must lead to sharable theories that help communicate relevant implications to practitioners and other educational designers.
- Research must provide an account for how designs function in authentic settings. The account should focus on interactions that refine our understanding of the learning issues involved.
- Research relies on methods that can document and connect processes of enactment to outcomes of interest.

In the following sections I will discuss the methodology adopted in my study to demonstrate how it attempts to incorporate characteristics listed above and builds on methods proposed by the design-based research methodology.

3.3.1 Design and Conjectures

One of the main issues this research focused on was the issue of students’ lack of academic preparedness to undertake mathematics subjects in mainstream vocational courses. Within my own department in the TAFE Division I was closely involved with providing concurrent support to vocational students and developing programs to improve students’ understanding, knowledge and skills in mathematics relevant to their vocational courses. But as a small department located on one campus we could provide only limited support and access via our open access mathematics-learning centre to students located on six different campuses. In order to make mathematics support for students more easily accessible we turned to technology and began to explore the use of web-based support systems. The challenge for us was to come up with a web-based learning environment that would be accessible to students at the TAFE level and would lead to improvement in students’ use, attitude and performance in mathematics.

This goal of developing the learning environment was closely tied to our conjectures about the design and the context of intervention. A number of conjectures were formulated about the design using an extensive review of mathematics related websites and adult learning theories. For example, one of the basic conjectures in terms of design was that if we provide a platform for asynchronous discussion, students would be able to access support more readily by contacting mathematics support teachers in a flexible timeframe. In terms of learning context and the designed environment we proposed that teachers should blend their class teaching with online extension using our web-based environment and thought that in this way they would find it easier to incorporate interactive learning objects in their mathematics teaching. These two conjectures were closely related to the research question on exploring how students’ access and use an online environment for learning mathematics and we tested the effectiveness of these conjectures by classroom observations and analysis of WebCT data. Sandoval (2004, p. 215), while asserting the importance of design and theoretical conjectures, points out that, “designed learning environments embody design conjectures about how to support learning in a specific context that are themselves based on theoretical conjectures of how learning occurs in particular domains”.

3.3.2 Cycles

Design-based research takes place in iterative cycles to refine the learning environment. This research study followed two distinct iterative cycles of design, enactment, analysis and redesign. The first cycle comprised of collaboration between two mathematics teachers and a researcher-cum-designer-cum-mathematics teacher in the initial concept and design of the web-based mathematics learning environment. This web-based product was then subjected to continuous cycles of enactment, analysis and revision. Both qualitative and quantitative data were used to evaluate the design and its implementation at the end of this first cycle in which 140 students and eight teachers were involved.

The second iterative cycle commenced with a revised and customised learning environment. The refinement and customisation were informed by findings and feedback from the first cycle of research. During this cycle of this research a more focussed study was undertaken to learn details of what use students made of this customised learning environment in which their course content was integrated with web-based mathematics content and support. Refinement of design was influenced by theories of "anchored instruction" which emphasise the importance of congruence between students' experience and the learning context (CTGV, 1992). Students' participation in and use of online activities during class sessions were observed and semi-structured interviews with selected students and the teacher were conducted to clarify meanings and interpretations and explore their feelings and attitudes in learning mathematics in a blended learning format. During this iterative cycle a quasi-experimental method was also used to ascertain empirically changes in students' attitude and performance to respond to the research question on how students' attitude towards mathematics and performance in achievement tests may be affected by the use of an online learning environment in teaching.

3.3.3 Shared Theories

Design-based research also leads to formulation of useful theories to inform practice. In this research in both iterative cycles, useful theories were generated for particular contexts. Based on qualitative and quantitative data and empirical evidence initial conjectures were refined in relation to the design of the environment as well as for factors that influence the outcome of intervention from both teachers' and learners' perspectives. These were presented in various conferences and journal publications for dissemination to peers (Javed, 2005a, 2005b, 2005c; Javed, Canty, & Samarawickrama, 2000; Javed & Vale, 2006).

3.3.4 Accountability

The methodology of design-based research also demands that accounts of design and intervention be documented to demonstrate the details of engagement with the learning environment not only to show how it worked but also to account for what interventions led to successful or unsuccessful outcomes. This study was a collaborative and participatory study and included forms of data collection that provide evidence for developing "thick descriptions" and a narrative account of practice as it unfolds in the context of classroom practice (Lincoln & Guba, 1985). I used notes from classroom observations, electronic responses via email and discussion board, student journal logs and interviews with selected students and teachers to generate a descriptive account of the iterative cycles in this research. In Chapter 4 and Chapter 5 of this thesis these accounts are presented as practice described and in Chapter 6 they are presented as practice interpreted to advance our understanding of the design and intervention during this study.

3.3.5 Connections

According to design-based research descriptive and empirical accounts rely on methods that are able to show the connection between the processes of enactment and outcomes derived. Many researchers are sceptical about claims of causality especially when applied to educational practice (Carr & Kemmis, 1986; Denzin & Lincoln, 2000). Sandoval (2004) emphasises the importance of qualitative description when assigning a specific enactment to a particular outcome. He comments that "The way the design is actually enacted has to be documented to understand which aspects of the now-changed environment contribute to observed outcome, desired or not" (Sandoval, 2004, p. 220). This aspect of the methodology was more explicitly implemented in the second iterative cycle when the online environment was enacted with a particular group of students for a period of one semester.

This cycle provided a unique opportunity to use a quasi-experimental method including a treatment vs. control comparison, as well as pre and post comparison for measurements of students' attitudes and achievements. Results from these comparisons were not broadly generalisable and were applicable to the specific contexts in which they were applied, but provided very useful indicators for interpreting qualitative data from interviews, classroom observation, engagement with the online environment and participation in electronic discussions.

Cobb et al. (2003) point out that design experiments have both a prospective and a reflective face. On the prospective side, "design experiments are implemented with a hypothesised learning process and the means of supporting it in mind in order to expose the details of that process to scrutiny" (p.10). While on the reflective side, design experiments are conjecture driven tests where continuous analysis and reflection during the study leads to generation and testing of "more specialised conjectures" (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003, p. 10). The prospective side of the study involved testing of hypotheses regarding students' attitude and achievement. It was assumed (conjecture) that integration of web-based tasks and activities along with face-to-face teaching would allow students better learning opportunities and lead to more positive attitude and better performance in grades. The reflective side of the study involved designing of individual online learning tasks and testing conjectures about their accessibility, use and effect on students' learning. This aspect was documented using descriptive statistics and qualitative methods such as participant observation, WebCT logs and interview questions.

3.4 Research Cycle 1

This cycle of the research comprised processes associated with the design and development of the online learning environment and subsequent field trials in the form of enactment followed by an analysis and refinement (Figure 3.1). The initial development of the online environment was inspired by the success of “Ask Dr Math” website (Drexel University, 2000). The development of this online environment was greatly assisted by the availability of a range of interactive mathematics learning tools online, students’ willingness to engage with new technologies and funding support from my institution.

3.4.1 Design Stage

The research cycle consisted of a design stage where two fellow mathematics teachers and I worked together to conceptualise and develop an online learning environment. Institutional support was provided through project seed funding to create a web-based learning environment to support those students who needed additional resources to complement their classroom learning. It was assumed that students who are facing basic mathematics skills and concepts would be able to extend their classroom learning experience with the help of access to an online learning environment which provides flexibility of time and space (conjecture). It was also expected that mathematics teachers would be able to integrate this web-based learning environment to provide scaffolding to those students who needed basic skills and conceptual development in topics relevant to their courses (conjecture).

The design of the learning environment was informed by a comprehensive review of resources and tools available on the Internet. The team of teachers involved with the project generated a comprehensive list of Internet websites relevant to teaching mathematics in TAFE. Each member of the team shared these sites and reviewed them for their content suitability and design accessibility. A comprehensive plan of the proposed website, Maths Concurrent Assistance (MCA) Online, was presented to a reference group of nine experts from the field and their feedback on design was noted. The online environment (MCA Online) consisted of 12 learning units developed by the team and included interactive Java-based exercises. The online environment also had tools for both synchronous and asynchronous communication (Appendix 1). The conjecture behind this design element was that students would use the discussion board to ask questions and respond to questions posed by others (conjecture). I, as the lead agent/researcher/teacher/developer in this learning innovation, had the main responsibility for the creation and refinement of this learning environment.

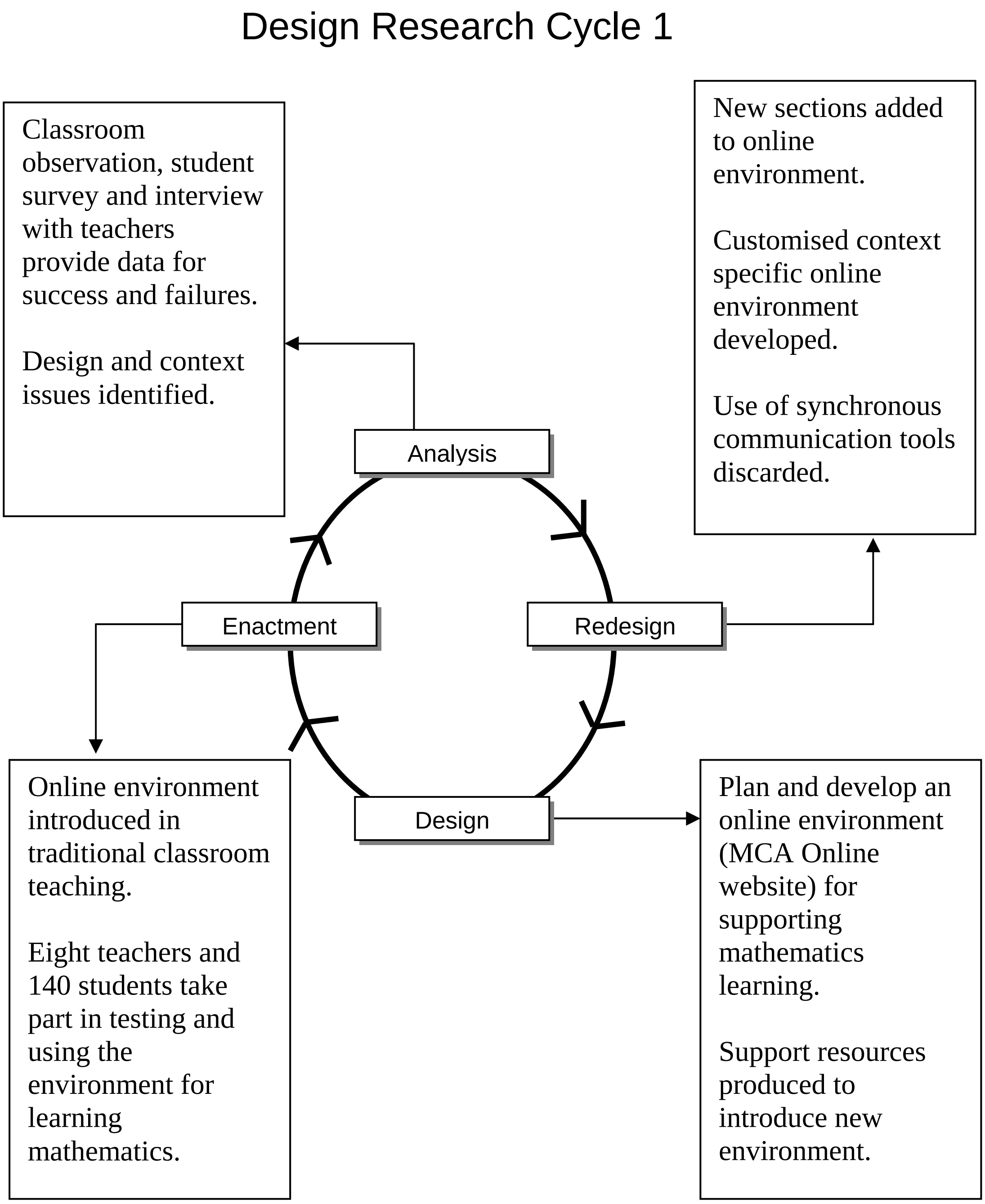

Figure 3.1. Design Research Cycle 1.

3.4.2 Enactment Stage

The enactment Stage of this cycle comprised implementing the new online learning environment in real classroom settings. The main objectives at this stage were to promote the new learning environment to teachers and students of TAFE, identify key issues in its operation by students and teachers, and collect feedback for refining the product.

The learning environment (MCA Online) was implemented in three modes over a period of one year. Firstly, in an open access mode, it was set as a default home page on all five computers in the Mathematics-Learning Centre (MLC) in the adult education department. In this mode it was offered to all students accessing MLC for seeking help in mathematics. MLC teachers were inducted in the use of MCA Online and students' use was documented in student record sheets on an ongoing basis. The record sheet noted what sections of the website were used by the student and if there were any problems encountered.

Secondly, in a classroom environment it was introduced as a module of activity. Students enrolled in Electronic Engineering, Business and Marketing, Women's Education, Language Studies and Adult Basic Education programs participated in an 18-hour module that aimed at equipping students with the necessary skills to use the MCA Online website to support their course related mathematics learning needs. A student questionnaire, discussion board postings and teacher interviews were used to collect data at this stage. Any content or design issue raised by a students or a teacher was immediately acted upon to refine the design of the learning environment.

Thirdly, the MCA Online website was used in conjunction with face-to-face teaching with a group of students enrolled in a general mathematics course for adults over a period of one semester. In this mode mathematics was taught in a conventional face-to-face mode but the MCA Online website was used as an extension activity to complement face-to-face learning. Classroom observation, performance on assessment tasks and discussion board postings were the main sources of data from this mode.

Overall, 140 students and 8 teachers took part in the enactment stage of this cycle of the study. Students were a mix of adult general education students and students enrolled in trade and vocational courses.

3.4.3 Analysis Stage

Since the purpose of this cycle of the study was to promote, refine and confirm or refute our basic assumptions about the design and use of this learning environment, our analysis of data was focussed on the purpose of refinement of the learning environment and finetuning our understanding about how the intervention works in the real classroom context.

During this cycle data were collected from three sources: teachers, students and the Internet. Teachers provided data at two levels. On one level, teachers provided spontaneous comments based on their immediate experience of the learning environment. These related to day-to-day technical issues related to access and use, and content issues about accuracy of information provided or requests for additional content. This was done by teachers in face-to-face contact and via email messages posted either to the researcher or to the email address for the learning environment. The messages sent to the website address were also collected at my email account. At the other level, teachers responded to a structured open-ended questionnaire that sought their response on interface design, content relevance and learning issues. Students' engagement with the online learning environment was analysed using class observation notes, web board postings and responses to a survey questionnaire. The survey questionnaire comprised 12 questions and sought students' feedback on their ease of access, relevance and preferences on using the MCA Online website (Appendix 9).

Teacher responses, notes from classroom observations and printouts from emails and web board discussions formed the basis for a thematic analysis of the qualitative data. Descriptive statistical methods were used to analyse and present data from the student survey. In addition, data from three different modes of intervention using the same web-based learning environment provided a useful comparison of how students engaged with, and used, this new learning environment. A summary of how the analysis of data during this cycle contributed to answering research questions is provided in the Table 3.3.

3.4.4 Redesign Stage

This stage refers to the final phase of the first design research cycle. At this stage analysis of data collected from teachers and students during the enactment of the MCA online in three different modes helped the refinement of our initial conjectures and led to important decisions about the design of the learning environment and the context of learning contributing to its adoption. Based on the findings of the first research cycle, new conjectures were drawn and a customised online learning environment for a specific course was planned for further study in the second cycle of research.

3.5 Research Cycle 2

The second cycle of research focussed on an in-situ study of the developed online learning environment (Figure 3.2). During the initial research cycle the MCA online had already been extensively trialled with different student groups and initial conjectures about its design, content and usefulness led to formation of tentative findings. These tentative findings provided the scope for the second cycle of this research where the online learning environment was customised to suit a particular learning context. Two classes enrolled in a Diploma of Business and Marketing course at their first year of study participated in this cycle of the study. A mathematics teacher with more than 10 years experience of teaching in TAFE courses taught an Introduction to Business Mathematics module to both groups. One class with 24 enrolled students was selected for blended online learning experiment and the other class with 19 enrolled students served as a control group where teaching was conducted in the traditional face-to-face mode and use no online resources were used. Section 3.5.1 of this chapter discusses the rationale and methods used in designing the customised learning environment for this cycle of the study. In Section 3.5.2 the enactment stage is presented to show the details of the module and how it was taught during this cycle. It is followed by Sections 3.5.3 where different instruments and tools used for the data collection are discussed. Section 3.5.4 provides details of the qualitative and quantitative data analysis applied during this cycle of research.

During this cycle the research focussed on designing and implementing a blended learning environment where web-based resources and activities were used to support and enhance the teaching of the mathematics module. This cycle of the study was used for further exploration of the research questions related to factors affecting students’ participation and issues concerned with the access to and use of a blended learning environment. The research design during this cycle was particularly relevant for answering the research question related to how the use of online learning environment affects students’ achievement and attitude towards mathematics. A summary of research questions and how the methods used in research cycle 1 and 2 were used to find answers for these questions in presented in Table 3.3.

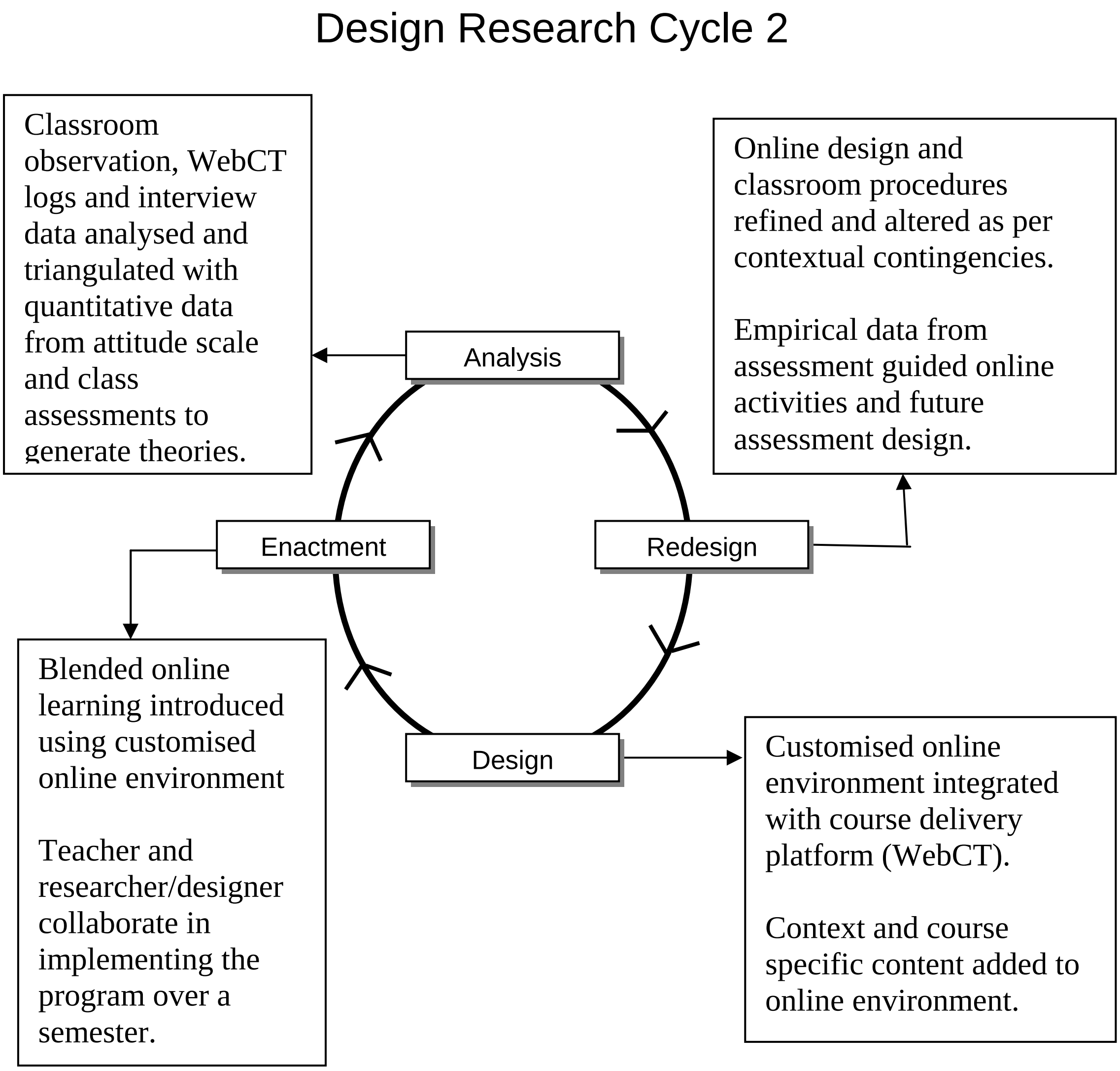

Figure 3.2. Design research cycle 2.

3.5.1 Design Stage

The design stage of the second cycle was concerned with two things. Firstly, it focussed on revision and customisation of the online learning environment to suit the context and objectives of the learning intervention. During the first cycle, learners' interaction with the MCA online environment was recorded only in the form of discussion board postings. The system was unable to register students' use of other sections and resources unless they were observed during a class. We needed a detailed picture of students' access to and interaction with the online environment and this led us to the second cycle design where we customised the design so that learners had to use a WebCT portal to access MCA online resources. The WebCT interface allowed us to control the learning environment so that only selected parts of the whole MCA online were available to students. The WebCT platform recorded students' access to and use of various sections of the website in an ongoing manner. This was a critical change from the previous design where empirical evidence of students' participation in different online activities could not be generated through technological means.

Secondly, this research cycle was concerned with developing a model for a blended learning environment, which meant putting together strategies to mix face-to-face learning in mathematics with relevant online activities carried out via the WebCT interface. During the first research cycle this blending aspect did not receive enough attention as the research was more focussed on familiarising students with a new learning environment and refining its content and design. During the second research cycle, the business mathematics teacher and I worked collaboratively over a period of one full semester to plan, design and implement the blended learning environment. This collaboration meant that the planning and implementation of the intervention was managed jointly and collaboratively. The intervention was continuously tweaked and fine tuned according to needs of students and course requirements.

The design element also included an experiment to compare relative achievement scores and attitude of students who participated in this intervention with another group of students who were taught the same content by the same teacher in a traditional mode in which no online learning was used. The purpose of this experiment was twofold. At one level, the comparison between control and treatment group was likely to indicate if the intervention produced any discernable effect on the measures of attitude and performance, and at the other level, using pre-post test comparison, it was possible to identify particular students for a more in-depth investigation. For example, using pre-post test data from the experiment it was possible to identify particular students showing a strong or weak performance in test results, allowing the researcher to use interview and other qualitative data such as classroom observation and WebCT logs of postings to examine particular cases more closely for any patterns and possible explanations. As indicated in design research studies conducted by Brown (1992) an experimental method mixed with appropriate qualitative methods can provide useful information to carry out “more in depth probing of a subset of students” (Brown 1992, p.157).

3.5.2 Enactment Stage

The module selected for this study was a 30-hour introduction to business mathematics module delivered in a face-to-face mode. It covered mathematical skills of algebra operations, simple and compound interest, depreciation, break-even analysis and graphic representation of data. These areas of study in mathematics were well supported by online learning units available on the MCA website and we did not need to invest too much effort in creating new online support resources from scratch. Another advantage of using this module for the study was the fact that the teacher teaching this module was a reference group member of the MCA online development and had taken a keen interest in the development and implementation of the MCA online learning environment during the first research cycle. Cobb et al. (2003) have emphasised the importance of the cultivation of ongoing relationships with practitioners in design-based research where the research work extends over a long period of time.

In terms of assessment the module followed a competency-based model and was divided into six learning outcomes. In order to pass, students had to demonstrate satisfactory competence in each learning outcome of this module. The assessment consisted of completion of set pen and paper assessment tasks at the end of each topic and an end of the course final test administered during the final week. This final pen and paper test covered all learning outcomes and was used to determine the final pass grade of the student.

With the help of the course coordinator we were successful in arranging a multi-purpose classroom with networked computers for our mathematics module. The multi-purpose classroom had a horseshoe formation for computers along three walls and there were rows of desks in the middle. This formation allowed the use of the same room for traditional face-to-face as well as blended mode teaching. Using our experience from the first research cycle of this study we decided on developing a WebCT version of the module that allowed us to integrate course content and online interaction more closely. During this cycle we were attempting to present online tasks and activities as a natural extension of face-to-face teaching, rather than extra optional work. The WebCT tools provided us access to useful data for tracking students' use of online resources.

In order to cover set learning outcomes for the module we decided to keep the learning tasks similar for both control and treatment groups. For the treatment group (blended mode online class) all learning activities and tasks were posted weekly on the WebCT module home page. For the control (traditional mode face-to-face only) group the learning activities and tasks were given in the print format. In addition, the treatment group was given online activities to extend and complement their face-to-face learning on individual topic areas. Students were given clear instructions that the online activities were an integral part of the course work and at least two weekly assessment tasks were based on online activities.

5.5.2.1 Sample Details

Two classes enrolled in a diploma course at their first year of study participated during this cycle of the study. A mathematics teacher with more than 10 years experience of teaching in TAFE courses taught both groups. One class with 24 enrolled students was selected for the blended learning experiment and the other class with 19 enrolled students served as a control group where teaching was conducted in the traditional face-to-face mode without the use of MCA online website. The researcher assisted the subject teacher in designing, developing and monitoring online activities for the treatment group and participated in classroom activities as a participant observer. The class was informed about the nature of the intervention and the role of the researcher in implementing, participating and observing this class. Both classes were held in the same location, a dual-purpose classroom/computer laboratory.

Although the control group was smaller in size compared to the treatment group, the profile of students in both groups was similar in terms of gender, ethnicity, previous educational level achieved, part time work commitment and access to Internet from home. Students in both groups were allocated by a central enrolment management system and had satisfied the pre-requisite criteria for selection into the course. In both the treatment and control groups most students had completed their VCE in the past two years and were under twenty years in age. Two students from the treatment group were older than 25 and had completed only Year 10 qualifications. Apart from more students in the treatment group working part time and having access to Internet from home, both groups had a fairly similar ethnic mix with the majority born overseas.

Table 3.2
Profile of treatment and control group students

	Treatment Group (*n*=24)	Control Group (*n*=19)
Male	58%	58%
Female	42%	42%
Working part-time	63%	47%
Have internet access from home	83%	68%
Speak another language	71%	84%
Born Overseas	54%	74%
Completed Year 12 in last two years	92%	89%

5.5.2.2 Data Sources

Data collection employed a number of quantitative and qualitative data gathering techniques. These included:

Aiken's Attitude Towards Mathematics Scale

Measures of attitude were obtained using an adapted version of the Aiken's Attitude Towards Mathematics Scale (Aiken, 1974; Drexel University, 2001) (Appendix 2).

The original scale included Likert scale format for recording responses but an adapted version by Drexel University used a Yes/No format for responses. This attitude scale consists of 10 positive and 10 negative statements about mathematics and students have to record their agreement or disagreement with the statement on the response sheet. Some positive and negative statements from the scale were:

- Mathematics makes me feel secure, and at the same time it is stimulating.
- I do not like mathematics, and it scares me to have to take it.
- Mathematics is something that I enjoy a great deal.
- When I hear the work the word math, I have a feeling of dislike.

Agreement with a positive statement scored +1 and agreement with a negative statement scored –1. An undecided or unanswered statement scored a zero mark. At the end scores from twenty items were added to give a total that ranged between –20 and +20.

Aiken Attitude Towards Mathematics scales have been used in educational research for a long time and various versions of these scales have been developed over a period of more than thirty years. At least three versions of Aiken's mathematics attitude scales have been reported in a review conducted by Taylor (1997). The Aiken scales are particularly useful for teachers due to their simple design, brevity and ease of administration (Taylor, 1997). The scales used in this research were originally developed by Aiken and Dreger (1961) after questioning 310 college students and Aiken (1996) has noted that the test retest reliability coefficient levels of these scales lie between .80 and .90. A number of researchers acknowledge that the Aiken attitude scales are well suited to post primary and college grade students for study of attitude towards mathematics (Chapman, 2003; Taylor, 1997). My interest in using this scale was guided by the fact that it was suited to the student cohort for this study, it was short and used simple statements and took about 20 minutes only to administer. Its use by a number of researchers in recent studies (Bassette, 2004; Chapman, 2003; Drexel University, 2001; Yushau, 2006) and empirical measures of its reliability indicated to me that it was a trustworthy tool and I could use it in my research with confidence.

Mathematics Achievement Pre-Test

The study used a general mathematics information sheet (achievement pre-test) to measure and compare students' mathematical competence at the start of the course (Appendix 3). The mathematics achievement pre-test was labelled General Mathematics Information Sheet in order not to provoke students' mathematics anxiety by using the term test at the start of a course (Ashcraft, 2002). The purpose of the test was explained to students and they were assured that their performance on this test would not make any difference towards their assessment or grading during this course. The test was developed in-house and contained ten general mathematics items of high school level covering number skills, fractions, ratios, percentages, simple algebra transposition and linear graphing. Test questions were modelled on an existing placement test used for the adult general education course and were verified for their accuracy and validity with two mathematics teachers from the adult general education department. The general mathematics test was administered to both the treatment and control groups during the first session. In terms of research, the purpose of this test was to gain an awareness of students' pre-requisite knowledge and skills in mathematics before participating in this course and use these scores as pre-test scores for mathematics achievement. This pre-test also provided a measure for finding out if the treatment and control groups differed in their mathematical abilities at the start of the course.

Student Journals

Students were asked to keep a journal of their Internet use during this course. The journal was designed in a semi-structured format so that students could focus on responding to prompt questions provided on the journal log form (Appendix 4). Sample questions and prompts to help them provide relevant information easily included:

- How many times did you go on the Internet during last seven days?
- Where from did you access the Internet?
- How much time did you spend on the Internet?
- What were your main activities on the Internet?
- Give a short account of how you used the *Internet for educational purposes.*

The purpose of this weekly journal was to record students' own reflection of Internet use and required them to provide details of their Internet access and for what activities they had used Internet. The information provide via this journal helped in answering the research question related to how students access and use the online resources for learning.

Student Interviews

Interviews with students were conducted during the final two weeks of the course. Students were advised to make individual appointments with me for this interview session and the classroom teacher was not present during the interviews. Six students from the treatment group and three students from the control group were invited to interview sessions. More students were selected for interview from the treatment group because the main focus of the research was to investigate issues related with the design and process of implementing an online learning environment. All interviews were recorded on an audio-tape and transcribed into a word processing package.

The interview with students followed a semi-structured format and interviewees were probed for clarity and more detailed responses. The semi-structured interview followed an "interview guide approach" (Patton, 1987, 2002, quoted in Johnson & Turner, 2003, p. 305) where the researcher used a set of predetermined questions with the interviewee but allowed the interview to follow a conversational path in order to gain an in-depth understanding of the issue. The interview guide contained 21 questions in all but some questions required only brief responses. These questions were only confirmatory in nature. Other questions were designed to explore the issues of attitude, learning preferences, attendance, access, design, assessment and online participation in detail. Some questions given in the interview included:

- Tell me about your reasons for doing this course.
- Do you think that using the computers and Internet can make learning easier for your course? How?
- What contribution do you think the course homepage made in your learning during this course?
- What main issues concerned you about accessing and using the course home page?

The interview took place after an initial analysis of WebCT data and assessment data comparisons were completed. This provided us with the opportunity to selectively probe high achieving and low achieving students for the factors contributing to their performance. Three high achieving students (final score greater than 60%) and three moderately achieving students (final score 60% or less) were selected for the interview to provide a perspective from a range of students. As a researcher I was constantly aware of the risk of being judgemental during the interview process and avoided comments that could influence students' responses to interview questions. (See Appendix 5 and 6 for the interview guide and a sample transcript).

Classroom Observation

Students in the treatment group were observed for the duration of a full semester and observation notes were generated immediately after each session. Johnson and Turner (2003) refer to Gold's (1958, quoted in Johnson & Turner, 2003, p. 313) description of qualitative observation as a continuum where the researcher can be identified as a complete participant on one end and a complete observer on the other end. The researcher can also be a "participant as observer" where he/she spends considerable amount of time inside the group or an "observer as participant" where he/she spends only a limited amount of time inside the group. I would classify my observation in this research as a "participant as observer" because I was with the group during all of the teaching sessions and spent a good deal of time with the teacher planning and designing the learning activities.

WebCT Access Logs

Another instrument to gather data during this cycle of the research was the electronic course delivery platform – WebCT. As a researcher and designer for this course I had administrator privileges to access this course home page. This allowed me to access to records of students data on their visits to particular sections of the WebCT website, their postings to the discussion board, other students and the teacher, and the amount of time students had spent on each section or activity on the website. These data from the website were transferred to an excel spreadsheet for detailed analysis and corroboration with test scores and interview data.

Final Test

The final test for the course was used as a post-achievement test and the same test was given to both the treatment and control groups. This test consisted of 13 questions covering the range of topics covered during the course (Appendix 18). Questions were short answer type where students had to show their working out for each question. Atleast two questions from each topic were included. The test lasted for one hour and was administered in the final week of the semester.

Teacher Interview

Another data source used in this study was a teacher interview at the end of the course. Although discussions with the teacher were held on an ongoing basis during the implementation of the Cycle 2 of this study and she was involved in the design of the online learning environment from an early stage, it was important to document her reflections about the blended learning experience. Sample questions used as a guide included:

- What are your expectations from the students in this mathematics module?
- In order to include online learning in your module what logistical and curriculum preparation did you need to do?
- Compared with your conventional teaching, how does inclusion of online learning impacts on your teaching?
- How effective do you think you have been in your online teaching?
- What factors may have influenced the success of your online teaching?
- How the use of online methods has affected teacher-student communication for you?
- As a result of this trial, how do you feel about your approach to computers and online learning, and do you think it has changed your attitude to using the Internet in your teaching?
- What would you do differently if you do this kind of teaching again?

3.5.3 Analysis Stage

During the second research cycle both quantitative and qualitative data were collected from two participating groups of students. Qualitative data from classroom observation, interview transcripts, students' journal logs and WebCT records were used to answer the research question on factors affecting students' participation in blended learning environment (Table 3.3, Q1). Coding and constant comparison of data from classroom observation and interview led to identification of categories as personal, design and structural factors. Both descriptive statistics and snapshots created from interview data were also used to verify and refine our conjectures related to students' participation in mathematics learning in a blended learning environment. In order to explore the research question on the effect of a blended learning environment on the teacher's role (Table 3.3, Q2), analysis of class observation, WebCT postings by the teacher and the transcript of teacher's interview were used in conjunction with researcher's personal reflections as an active participant in designing and implementing the online learning environment. Themes and categories generated through analysis of qualitative data were used to generate theories about the teacher's role in blended online learning. Similarly, WebCT records of students' participation, classroom observation, student journal logs and interviews with selected students provided data for answering the research question on how students access and use a blended learning environment (Table 3.3, Q3). To explore this research question in detail data analysis required use of both statistical and qualitative techniques. Descriptive statistical methods were used to present findings in relation to access to online learning environment. Students' journal logs, classroom observation, WebCT records and interview questions were employed to produce a detailed picture of students' access to and use of online learning environment. Assertions about students' use of online environments in learning mathematics were supported and justified with the use of descriptive statistics and snapshots generated from interview and WebCT data.

Another level of analysis was applied to data obtained from experimental procedures to answer the research questions related to students' attitude and achievement (Table 3.3, Q 4 and Q5). The Statistical Package for Social Sciences (SPSS) software was used to analyse data obtained from quantitative instruments. The fourth research question sought to find out if the use of online learning environment affected students' mathematical achievement. An initial mathematics skills test was conducted on both treatment and control groups to see if there was a significant difference between the two groups at the start of the treatment. The final examination scores were compared to measure if two groups differed in their outcome in terms of mathematics achievement. No pre-post comparison was possible because the same achievement test as administered at the start would not give a valid measure, if administered again at the end of the course. Apart from pre and post achievement tests, ongoing assessment results were also used to explore associations between students' achievement scores and access and use of online resources via WebCT format. Data from achievement scores also helped in interpreting students' response to interview questions.

The final research question aimed at discovering the effect of online learning environment on students' attitude towards mathematics (Table 3.3, Q5). Results from administration of Aiken's Attitude Towards Mathematics scale were analysed using *t*-test and analysis of variance techniques. An independent sample *t*-test was conducted for all scores available for control and treatment groups. This measure was used to establish if the two groups showed marked difference in their attitude towards mathematics. Considering the fact that during the semester long course a number of participants had dropped out from both control and treatment groups, a *t*-test comparison using scores from students who were available for both pre and post tests was also conducted. This measure was applied in order to remove any perceived bias that may have been present due to changes in student profile of both treatment and control groups. Similarly, a post treatment *t*-test comparison between treatment and control groups scores for students was carried out to ascertain if significant difference existed between these two groups at a .05 significance level.

Pre-post comparison for paired sample scores was done for both groups of students to show the changes in attitude towards mathematics as a result of a semester of teaching. These measures were designed to show if the treatment group changes in their attitude towards mathematics were more positive than the control group. It is important to note that the purpose of these statistical measures was primarily directed towards answering research question five and not particularly concerned with making generalisations about the effect on online learning on student attitudes. The attitude scores were used in correlation and triangulation with information derived from interviews and observations to develop a comprehensive picture of students' use of the new learning environment. A summary of data collection and analysis strategies applied during research cycle one and two are shown in Table 3.3.

Table 3.3
Summary of methods used in Cycle 1 and Cycle 2 of research

Research Questions	Data Collection Strategy		Data Type	Analysis	Validation
	Cycle 1 (1999-2000)	Cycle 2 (2001)			
Q1. What factors affect students' participation in blended learning environment?	- Mathematics websites review - Design analysis of benchmark websites - Student questionnaire - Classroom observation	- Design analysis of customised WebCT site - Classroom observation - Student interview - Content analysis of course content and structure	Qualitative and Quantitative	- Exploratory examination and identification of key elements of design - Constant Comparative - Descriptive statistics	- Member check - Triangulation
Q2. How do students access and use a blended learning environment?	- Student Questionnaire - Classroom participation/ observation	- Classroom observation - Student Journal Logs - Student interview - Attendance roll - WebCT Access Logs	Qualitative and Quantitative	- Descriptive statistics - Themes generated	- Triangulation - Persistent observation - Evidence of negative case

Table 3.3
Summary of methods used in Cycle 1 and Cycle 2 of research

Research Questions	Data Collection Strategy		Data Type	Analysis	Validation
Q3. How does using a blended learning environment affect the teacher's role?	- Participating teachers' survey - Feedback (informal) from participating teachers (8) - Participant observation of class teaching Reflection on practice	- Prolonged engagement as a participant observer - Teacher interview WebCT logs WebCT postings	Qualitative and Quantitative	- Themes generated - Descriptive statistics	- Prolonged engagement - Check-recheck with colleagues - Triangulation with WebCT data
Q4. How does the use of online learning environment affect students' attitude towards mathematics?	- Student Survey - Classroom observation	- Pre- and Post-attitude test - Student Interview Questions	Quantitative	- *t* tests - Analysis of variance - descriptive statistics	- Statistical testing - Triangulation with interview data
Q5. Does the use of online learning environment affect students' mathematical achievement?	- Not applied	- Final Test (Post-achievement test) comparison with control group - Weekly test results - WebCT Access Logs	Quantitative	- *t* tests - Analysis of Variance - Correlation with achievement scores - Descriptive statistics	- Statistical Testing - Triangulation with qualitative data from question 2.

3.6 Quality, Trustworthiness and Alignment

Quality and trustworthiness of a research study are often associated with the measures of reliability and validity. Validity of a study refers to the “likelihood that our interpretation of the results accurately reflects the truth of the theory and hypotheses under examination” (Hoadley, 2004, p. 204). Reliability points to the “degree to which a measurement can be replicated” (Hunter & Brewer, 2003, p. 581). Reliability implies that repeated measurements of the same phenomenon are able to produce consistent results over a period of time.

Historically quantitative and qualitative studies have tended to rely on different sets of criteria for the establishing validity and reliability of their research (Johnson & Christensen, 2004; Maxwell & Loomis, 2003). In quantitative research quality and trustworthiness concerns are primarily related to four types of validity. Cook and Campbell (1979) refer to these as:

- Internal validity or causal validity: the validity with which it is inferred that the relationship between two variables is causal.
- External validity or generalisability: the extent to which the results of a study can be generalised to and across populations of persons, settings, times, outcomes and treatment variations.
- Statistical conclusion validity: the validity with which it can be inferred that two variables are related and the strength of that relationship.
- Construct validity: the extent to which a theoretical construct is accurately represented in a particular study.

On the other hand qualitative researchers are often not concerned with exploring causal relationships between variables and their notion of validity of research outcomes tend to rely on a different set of criteria (Guba & Lincoln, 1989). Qualitative researchers prefer to use terms such as plausible, credible, trustworthy and defensible to describe their research outcomes. However, issues of validity are important to qualitative researchers as well and Maxwell (1996) identifies three types of validity that are applicable to qualitative research:

- Descriptive validity: refers to validity of the descriptions of settings and events
- Interpretive validity: refers to validity of statements about the meanings or perspectives held by participants.
- Theoretical or explanatory validity: refers to validity of claims about causal processes and relationships.

Johnson and Christensen (2004) note that qualitative researchers need to be aware of the threats to the credibility of their research due to influence of “researcher bias”. They point out that researcher bias results from “allowing one’s personal views and perspectives to affect how data are interpreted and how the research is conducted” (p. 249). However, most qualitative researchers are not concerned about the subjectivity associated with their research (Denzin & Lincoln, 2000) and often they use “reflexivity” as a means to achieve credibility. Johnson and Christensen (2004) describe reflexivity as “self awareness and critical self reflection by the researcher on his or her potential biases and predispositions as these may affect the research process and conclusions” (p.249).

Qualitative research methods also employ a range of techniques including triangulation, peer review, member check, participant feedback and negative case sampling to enhance the trustworthiness of their research outcomes. The qualitative part of this study included measures such as participant observation, WebCT postings and interview. I employed data triangulation and method triangulation techniques to corroborate findings drawn from quantitative and qualitative techniques employed during this study.

Design-based research treats the notion of quality and trustworthiness differently from purely quantitative and qualitative research. The Design-Based Research Collective (2003) highlights that design-based research, “typically triangulates multiple sources and kinds of data to connect intended and unintended outcomes to process of enactment” (p. 7). It points out that the “reliability of findings and measures can be promoted through triangulation from multiple data sources, repetition of analysis across cycles of enactment, and use (or creation) of standardized measures or instruments” (p. 7).

Hoadley (2004) coins the term “alignment” to address the issue of validity in design-based research. He argues that the emphasis on partnerships and iteration in the design-based research process increases the alignment of theory, design, practice and measurement over time in complex realistic settings like the classroom. This kind of alignment is not possible in simple single experimental design research.

At one level, Hoadley (2004) is concerned with the issue of alignment of the treatment with the theory. He characterises this alignment as treatment validity and asserts that we need to ensure that the “treatments we create accurately align with the theories they are representing” (p. 204). At another level, Hoadley (2004) is also concerned about methodological alignment. He notes that the “process of forcing the same people to engage the theory, the implementation of intervention, and the measurement of outcomes encourages a greater degree of methodological alignment” (p. 205). For Hoadley this alignment is crucial for establishing systemic validity in design-based research. According to him, “to achieve true systemic validity our studies must inform our theories, which must inform practice” (p. 205).

Both treatment and methodological alignment were present in this research study. The design of an online learning environment and its implementation in adult learning contexts was based on adult learning theories and used assumptions that aligned with theories of mathematics learning relevant to adult vocational education contexts. The study used a partnership approach where the researcher, designer and teachers worked collaboratively and were responsible jointly for designing and implementing the intervention (methodological alignment).

Design-based research is not concerned with broad generalisability of research outcomes and as such ignores issues related to external validity. Hoadley (2004) argues that “universality is rare in educational phenomenon and because methods take tentative steps by first examining individual contexts, design-based researchers generalise their findings only tentatively” (p. 205). Because design-based researchers are involved in the process of intervention as participant observers and because they play an active role in manipulating the environment they study, Hoadley points out that it becomes imperative for them to describe and monitor ways in which the results may be influenced by their own agenda. Hoadley asserts that “design-based researchers not only document their perspective or starting point, but must also document any plausibly relevant interventional strategies used not only by participants observed, but also by the researcher herself or himself" (p. 205).

In this study I have taken particular care to present the design and intervention as a narrative that describes the history and practice of the researcher and the context within which this intervention is located. The research has involved a number of practitioners and students and care was taken to document the practice in an ongoing manner. Member check and peer review have also been helpful as papers resulting from this research were shared with colleagues for comment and presented in seminars and conferences (Javed, 2005a, 2005c; Javed & Vale, 2006). As the research took place in an online learning environment mixed with face-to-face teaching, details related to particular activities and interventions were accessible from online records on WebCT. Because access to computers and email was available from all sites, I took field notes and emailed them to myself for later recollection. These strategies helped me document the practice in detail and at the same time I was able to clarify my personal perspective and possible effect it could have on outcomes in a reflexive manner.

Another source of ensuring rigour in design-based research is its reliance on multiple methods and multiple sources of data (Cobb et al. 2003). Design based research does not exclude controlled laboratory experiment from its methods (Brown 1992; Cobb et al. 2003). Hoadley (2004) advises that design-based research should not be seen as a "prescientific" method which is interested in merely hypothesis generation. He contends that " In areas where controlled experimentation may be used to adequately test a hypothesis, the experimental paradigm is a powerful means for conferring causal relations" (p. 205). Brown (cited in Design-Based Research Collective, 2003) has argued that experimental methods when used in conjunction with useful qualitative methods can be very helpful by "assisting in the identification of relevant contextual factors, aiding in mechanisms (not just relationships), and enriching our understanding of the nature of the intervention itself" (p. 6).

I employed an experimental design during the second cycle of research to gain a better understanding of the relationship between students' attitude towards mathematics and if the treatment had any affect on their attitude. The experimental design also helped in comparing the performance of treatment group with a control group, but more importantly, the experiment helped in drawing our attention to factors not originally being followed in the study, such as the effect of online intervention on continuous assessment tasks. The experimental design followed the criteria of internal validity and causal validity but it was not our concern to address the generalisability criterion because the goal of this research was to gain an understanding of a particular intervention as it unfolds in a particular setting and to develop tentative theories applicable to particular contexts and ecologies that bear semblance to the one described in this research.

3.7 Conclusion

This chapter has presented the methodology followed in this research from both theoretical and a methodological perspective to clarify that a pragmatic enquiry drawing on the principles of constructivist theories is most relevant for the purposes of this research. Adapting a methodological framework which used iterative cycles of design, enactment and analysis this research drew on a design-based research approach where a web-based learning environment for enhancing and supporting mathematics learning was developed, refined and tested in classroom settings. Data collection methods and instruments relied on a range of sources and instruments and included both qualitative and quantitative measures. The conjectures drawn in the design and enactment stages of the research cycle were reviewed and verified to draw tentative theories based on a rigorous analysis of data obtained from a range of sources. In the following two chapters details of the two research cycles are presented in detail to report on the conjectures, design and enactment processes used.

Chapter 4: Research Cycle 1

4.1 Introduction

A number of researchers following design-based research methodology have pointed out the importance of generating a comprehensive record of the ongoing design process (Cobb et al. 2003; Hoadley, 2004). They contend that researchers need to provide a detailed account of the context of the study, document the developmental process for the design and intervention and acknowledge their personal agendas or biases that may have an influence over the design and intervention. The first section of this chapter provides details of the personal, institutional and curriculum contexts for this study. It is followed by Section 4.2 which gives a comprehensive overview of the online learning environment and how it was developed. It provides details of the content included in the online learning environment and the rationale behind its design and content selection. Section 4.3 presents the implementation details of the online learning environment. In providing this description, I have drawn on documents, reports, minutes of meetings, emails, discussion postings, personal communication with teachers and classroom observations made during the implementation of the online learning environment. In Section 4.4 reflections from the design and implementation stages of this web-based learning environment are discussed and finally in Section 4.5 a summary of the chapter is presented showing how the findings from this first research cycle led to the next stage of this study.

4.1.1 Institutional Context

This study is located within the TAFE division of a large dual sector university in Australia where more than 20,000 students are enrolled in TAFE courses every year. The university offers a range of higher education and TAFE courses and these are spread over 11 campuses within the metropolitan region. It is the only public tertiary education provider located within a region of more than half a million people characterised by its cultural diversity. A significant proportion of the population of the region comprise of immigrants from non-English speaking backgrounds with a lower than average participation rate in tertiary education (Wheelahan, 2001). The student population of the university reflects the demographic profile of the region.

The University offers a range of educational pathways to students interested in articulating from TAFE certificate and diploma courses to higher education degrees but high attrition rates at both higher education and TAFE level courses are common and remain a constant challenge. Studies have reported that during the past ten years around 25% students have been dropping out from their courses during their first year of enrolment in higher education courses (Gabb, Milne, & Cao, 2006, p. 2). Although developing a clear understanding of this attrition rate is complex and multi-dimensional, the University has shown a recognition of the need to support students and teachers in dealing with the issue of attrition from courses (Milne, Glaisher, & Keating, 2006; Wheelahan, 2001). The university's student learning support and concurrent assistance programs are geared towards ensuring that students enrolled in TAFE and HE courses are able to meet their academic requirements successfully. This research also emerged from one such initiative from the TAFE division that aimed at enhancing mathematics learning and extending mathematics support to students who could have been at risk due to their poor numeracy and mathematics skills.

The TAFE division of the university where I worked offered courses in the Certificate(s) of General Education for Adults (CGEA) and youth and mature age students studied subjects like General Mathematics, Reading and Writing, English Grammar and Computer Skills either in a part time or a full time mode. The unit also included a concurrent assistance program that aimed at providing academic support to students enrolled in mainstream TAFE certificate and diploma courses. This academic support included helping students with their mathematics and English language skills. The concurrent assistance activity involved several forms of teaching including team teaching with the vocational teacher as a partner, running special workshops, group tutoring and one to one tutoring.

A significant change occurred when my unit received additional funding to establish a separate Mathematics Learning Centre (MLC) to assist TAFE students with their mathematics needs. A team of three mathematics teachers including myself took the responsibility of the development of this MLC. We assembled and developed a range of resources for hands-on learning activities, print based practice sheets, and problem solving tasks and computer based mathematics programs. The introduction of MLC and its success with students sowed the seeds for this design-based research project. The new project sought to extend the access and usefulness of the MLC by creating an online learning environment. The intention was to develop an online environment modelled on the best practice concept of a physical mathematics learning centre to offer access and support for mathematics learning through an interactive online learning environment. The impetus towards developing an online environment was also influenced by policy initiatives in the TAFE sector that encouraged and supported flexible delivery and online learning (Office of Post Compulsory Education Training and Employment, 2000).

4.1.2 Personal Context

As a mathematics and science teacher I have been working in the field of education for the past 25 years. During this period I have worked in the secondary, TAFE and teacher education sectors. Over the past fifteen years I have been involved with general education programs for adults and was responsible for developing and teaching mathematics and science modules for the general education for adults programs. During this time I have also worked with the concurrent assistance program where I offered learning support in science and mathematics to students from trade, science, engineering and business courses.

During my work in the TAFE sector I have taken a keen interest in the use of computers in numeracy and mathematics teaching. I was responsible for setting up the first computer lab for adult education students in my department. The period of nineties was a boom time in terms of introduction of computers in educational settings. I was interested in the Internet and arranged to bring Internet connection to our computer lab via dial up connections and designed the first website for my department. This experience allowed me to develop technical and design skills for publishing on the Internet. I was also able to find a number of freeware mathematics programs from the Internet for our computer lab. These programs allowed me to introduce computer-based learning in mathematics. Some of these programs were basic skills practice programs but allowed adult learners to learn to use computers and practise their maths skills in basic operations.

I was also interested in sharing my experiences and knowledge with other mathematics and literacy teachers and became involved with a number of professional development projects. Working as a coordinator for two national projects I took an active part in professional development of teachers in the use and application of technologies in classroom teaching. During these projects I came in contact with a number of teachers working in the vocational education sector who shared an interest in the applications of technology in learning. These projects also gave me new skills in online design and showed me new tools and web-based resources for learning.

Drawing on experience from these projects and working with fellow mathematics teachers I began to explore the possibilities of using online resources in the mathematics classroom. At first I was interested in downloading simple maths programs on skills practice and problem solving but soon discovered java and java script-based interactive online mathematics activities. The interactive online activities provided me an opportunity to explore computer-based problem solving with my mathematics classes. By mid 1999, the successful development of the Mathematics Learning Centre, the introduction of the Internet in computer labs, the discovery of various online learning resources and communication tools, and the availability of necessary skills for developing an online learning environment seem to have emerged as converging factors for me to initiate a project for developing an online learning environment and conduct a systematic study of the development and use of this new medium as a design research project.

4.1.3 Curriculum Context

Mathematics curriculum in the TAFE sector can be divided into three types. First there is the Adult, Community and Further Education (ACFE) based mathematics curriculum that conforms to the frameworks of Certificates of General Education for Adults (CGEA). This mathematics curriculum bears resemblance to mathematics taught in secondary schools but methodology is strongly influenced by adult learning principles (Knowles, 1980). Mature age and youth learners can move from Certificate I mathematics to Certificate III mathematics in a developmental pathway. There is a strong network of adult numeracy and mathematics teachers within Australia and globally and mathematics teachers from this area have access to professional development and research from the field (FitzSimons, 2003). Second, there is an adult VCE mathematics that is year 11 and 12 mathematics for those who wish to gain a VCE certification from the Victorian Curriculum and Assessment Authority (VCAA). The adult VCE mathematics follows the same mathematics curriculum and assessment as any secondary school year 11 or 12 student. Teachers teaching VCE mathematics are specialised mathematics teachers with a strong mathematical background. The third type of mathematics is the one taught in vocational and trade courses. The VET mathematics curriculum is strongly influenced by the particular industry sector of the vocational training and follows a competency based assessment. VET mathematics is the least theorised and very few research or professional development opportunities are available to mathematics teachers from the VET sector (FitzSimons, 2002a).

4.2 Development of MCA Online Environment

The development of an online learning environment to support mathematics learning at the TAFE level was a major project and required institutional support, funding and skilled teachers. Having played an active role in establishing computer-based learning activities at the Mathematics Learning Centre at my department and with ten years of experience in teaching mathematics to adult learners, I coined the idea of developing an innovative online learning environment and encouraged two of my fellow mathematics teachers to come on board for setting up this project. A number of government and institute level initiatives such as Australian National Training Authority’s Flexible Learning Framework (ANTA, 1998), Victorian Flexible Learning Strategy for TAFE (Office of Post Compulsory Education Training and Employment, 2000) and the learning and teaching strategy of my university provided a contextual backdrop and our department was able to gain funding from Victorian Open Training Services to carry out this project. The funding enabled time release for two mathematics teachers to work on the project one day a week for a period of one semester. It also enabled me to be assigned to the project on a full time basis for a period of one semester and coordinate the planning and development of the whole website.

Immediately prior to embarking on this project I had completed a research project (Wilson & Javed, 1998) where I explored the use of the Internet and web resources by literacy and numeracy teachers. This work allowed me to develop a broad understanding of issues related to online design and learning and encouraged me to embark on a research project to explore how an online learning environment can be developed and used to support mathematics learning. So, for me, the Maths Concurrent Assistance (MCA) Online project involved not only an innovative online design project, but also an evolving design-based research which focussed on articulating and refining tentative theories regarding the development, use and effectiveness of an online learning environment in supporting TAFE students mathematics learning.

The first stage of the project was the planning stage. During this stage we identified the desired objectives and personnel for the project. Two of my colleagues and I formed the core of the team and began the planning and development work for the project. Our head of department took the role of a project manager and acted as a critical friend during the project. An advisory group consisting of nine members from the field of vocational education met three times during the project and advised the development of the project. At this stage we took stock of our individual strengths and weaknesses in terms of skills required for the project. Research has shown that developing good online resources requires considerable skills and expertise on the part of teacher as a designer (Cashion & Palmieri, 2002; Ward & Newlands, 1998).

The two mathematics teachers brought considerable experience of teaching secondary and TAFE mathematics to the project and were working with students seeking mathematics assistance via our Mathematics Learning Centre. But they did not have any online design skills and used computers for word processing, email and web browsing purposes only. I came to this project with considerable skills in computer use and web design. In addition to teaching mathematics, I was also a teacher of computing skills and according to the classification developed during Literacy Learning Trough Technology (LLTT) project (Wilson & Javed, 1998, p. 15), my skills would have fallen under the ‘developer’ category. The project employed a graphic designer for a short period to help with developing graphics for the website. Two Information Technology experts were part of the advisory group and were available for any assistance. The two mathematics teachers and myself carried out the bulk of the content and site development and I played a lead role in guiding the design and assisting with writing mathematics units for the web.

4.2.1 Conjectures and Design

The design and development of the online environment, MCA Online (Javed, Canty, & Samarawickrama, 2000), was guided by a number of conjectures about the design. These conjectures were informed by teachers' personal experiences and an informed survey of literature on computer assisted mathematics learning (Bransford, Brown, & Cocking, 1999; Kaput & Thompson, 1994; McCoy, 1996).

Conjecture 1.1: Navigational scaffolding would allow students to focus on a particular learning path and avoid distractions resulting from browsing external websites

Our first conjecture was concerned with navigational scaffolding for students. Our design wanted to use existing web-based interactive learning objects on selected mathematics activities in a hypertext-linked environment. The problem of giving web addresses or expecting students to follow a link to a given website to find a learning object/activity often leads to frustrating searches and has the potential to lead students to diversions and time-wasting web browsing (Gerber & Shuell, 1998; Smith & Ferguson, 2005). In our design we decided to use navigational scaffolding so that from our online learning environment for a particular mathematics unit learners had direct links to learning objects located on the Internet. Through this approach we hoped to keep the student focused on a particular learning path and avoid distractions resulting from browsing external websites. In addition, this conjecture also allowed us to explore if students' access and use of the online learning environment was positively affected by our navigational scaffolding.

Conjecture 1.2: Interactive online activities providing immediate feedback to learners would be able to engage students' attention for longer and help in building students' understanding and use of mathematical concepts

Our second conjecture related to the issue of use of interactive learning objects. In this context interactivity referred to the ability of the online learning object to allow users to manipulate data input and observe its effect on the outcome. The Internet offers a range of JavaScript and java applet based learning objects that allow users to interact with the system to generate solutions. Loong (2001) has identified three types of interactive mathematics objects on the Internet but in our design we were concerned with using the interactive objects that provided feedback to users and were exploratory in nature. The type of interactivity generated through these objects is unique to computer-based systems only and cannot be achieved in paper based learning activities. Studies have shown that interactive tasks with immediate feedback enable the online medium to engage students' attention for longer than usual (Laurillard, 1997). We were not interested in the game play type of interactivity, as it was not expected to appeal to adult learners. Our assumption here was that the interactive online activities on our website need to help in building students' understanding and use of mathematical concepts. We also expected that these interactive learning activities would have a positive effect on students' achievement scores in mathematics tests.

Conjecture 1.3: Communication tools such as a discussion board and live chat would be able to extend students' access to the teacher's guidance and promote a culture where students could help each other in learning

The third conjecture that affected the design of the online learning environment was related to the use of communication tools. One of the key aspects of face-to-face teaching is the live teacher-student interaction and this class dynamism is unable to be reproduced in the online environment (Smith & Ferguson, 2005). However, research has shown that the availability of communication tools such as email, discussion board and live chat can be used to create effective online learning communities (Salmon, 2000). The Mathematics Learning Centre (MLC) provided students direct contact with teachers where they were able to bring their mathematics problems to seek guidance from a teacher in the MLC. The teacher guided the student in a face-to-face meeting with the aim of providing the student a support that would not only solve the student's immediate concerns but also lead him or her towards becoming an independent learner. The online environment provided the opportunity to extend the student's access to the teacher's guidance by means of synchronous and asynchronous communication.

By creating and using an online message board we expected that students would be able to post their questions in an asynchronous mode and teachers would be able to respond to students' postings. In this way, we were aiming to promote a culture where other students could also respond to questions and comments posted by students. In addition to the message board, the online environment design also incorporated an online live tutorial tool. This online tutorial tool was built to allow students to log on to the tutorial site at specified times and chat with a mathematics teacher in the online mode. Drexel University's Ask Dr Math (2000) online forum provided a good example of building a community of practice by using asynchronous tools of an online discussion board. Using the communication tools of discussion board and live chat, the MCA online design assumed that TAFE students seeking support in mathematics could also be trained to use the synchronous and asynchronous mediums for their learning needs. However, it is useful to note that the live chat option was a novel experience and very few teachers and students had used this medium for learning mathematics. With the use of asynchronous and synchronous communication tools in our online learning environment we wanted to find out how this new communication medium affects the role of the mathematics teacher.

Conjecture 1.4: Making discipline specific learning resources available through a website would encourage mathematics teachers to direct their students to use these resources and use this website as a reference in their regular face to face classes

Another important conjecture that played a significant role in the design and content of the online environment was that if we provided discipline specific resources from engineering, science, business, VCE and general education areas, students and mathematics teachers from these disciplines would be more inclined to direct their students to this online learning environment and also use this website as a reference with their regular face-to-face classes. This assumption led us to design sections of the MCA Online that were devoted to particular discipline areas and contained archives of questions and answers from past examinations, recommended book lists, module details and links to MCA Online learning units particularly relevant to that discipline. We anticipated that teachers and learners would readily use a web design that suited the needs of students enrolled in mathematics modules and offered access to learning in a flexible format. In the context of the study this conjecture allowed us to examine if relevance of online activity to students' immediate learning needs was a key factor in students' participation in an online learning environment.

4.2.2 Design Framework, Planning and Construction

Kuutti (1996) suggests that technology-based design needs to balance three levels: automating routines, developing understanding and fostering communication/creativity. A number of contemporary researchers have also highlighted interactivity and connectivity as important and useful elements of online learning environments (Alexander, 2001; Laurillard, 1997; Loong, Barnes, & White, 2002). Our design of the mathematics online learning environment was guided by our desire to make both interactivity and connectivity available to learners.

It is important to note that the intention of our proposed online environment was not concerned with distance education or learning remotely with the use of technology without direct assistance from teachers. Our goal was to offer an online environment that could extend the access and opportunities for students in classroom-based learning and encourage teachers in incorporating new technologies in mathematics teaching. It aimed at expanding teachers’ zones of promoted action (ZPA) and free movement (ZFM) (Goos, 2006).

The planning for the design of MCA online website started with the conjecture that if we created an online environment that offered content that engaged students without challenging their attention threshold and offered spaces for social interaction, we would be able to increase their involvement with mathematics learning beyond classroom contact. Studies have shown that interactive tasks with immediate feedback enable the online medium to engage students’ attention for longer than usual (Laurillard, 1997).

The MCA Online development process included planning and designing for the mathematics content provided in the online environment; planning and designing for the interactivity using external website links and Java-based resources; and planning and designing for the communication tools to be provided to users of this online environment.

4.2.3 Learning Units

Planning and designing for the mathematical content provided in the online environment was influenced by our conjecture that we should make available learning content that would be appropriate for the needs of students enrolling in engineering, science, business, VCE and general mathematics courses in the TAFE sector. Although working with students coming from different disciplines and using our Maths Learning centre (MLC) we had developed a fairly good idea of what areas of mathematics students needed help with, we decided to ask six teachers from vocational programs and VCE to list mathematics topics that would be most helpful in building students' concepts and skills in mathematics. In addition, we collected data from students of three vocational mathematics classes using a questionnaire for students' survey (Appendix 7). The survey aimed at identifying the kinds of mathematics problems students experienced in their courses. It asked three questions: 1. What maths module(s) are you studying this semester? 2. What maths are you having problems with? (Give names of topics or examples of questions) 3. Did you have any problems with your school maths? (If yes, name the topic).

In response to this survey, common topics listed by students and teachers included algebra, fractions, decimals, percentages and unit conversions. Some students also listed topics such as calculus and differential equations but we limited our goal to providing supporting learning units in only pre-requisite mathematics skills and broadly focused on mathematics of up to year 10 and Certificates of General Education of Adults (CGEA) levels. After discussions with project team and advisory committee, we decided to develop learning units on 12 topics. These topics were Algebra, Numbers, Fractions, Decimals, Percentages, Indices, Measurement, Trigonometry, Statistics, Geometry, Probability and Graphs (Figure 4.1). Each topic or learning unit was further divided into three or more subunits. The purpose of these learning units was to provide a basic understanding of mathematical concepts and techniques associated with these topics.

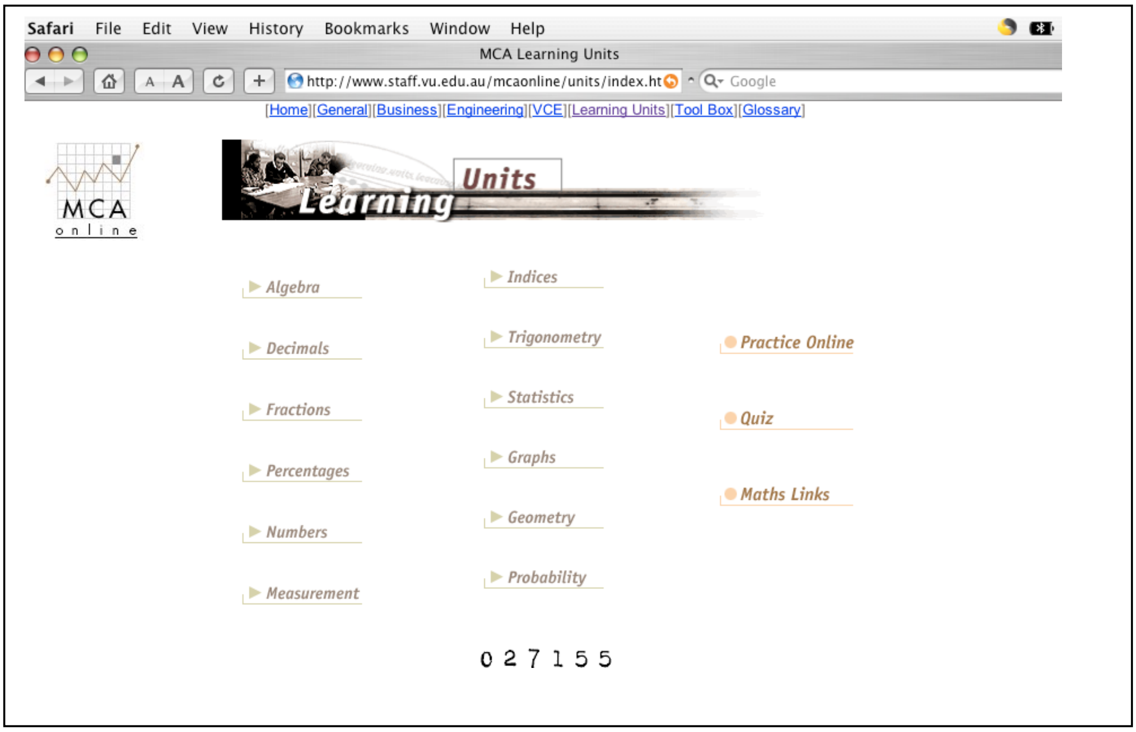

Figure 4.1. The learning units section of the MCA Online website.

The learning content and activities within each subunit of a topic were developed with a view of adult learning principles (Knowles, 1980) and used the design and interactivity elements of the web to offer a learning experience not possible with print-based resources. Each subunit (Figure 4.2) started with an *Examples* section where the basic concept was explained in simple language using a number of examples. Procedures for finding solutions for the example problems were elaborated and explained in a meta-talk along with the mathematical solution. The purpose of this meta-talk was to scaffold learners' conceptual thinking in the absence of a face-to-face teacher talk. The *Examples* section was followed by a *Have a go* section where learners were prompted to attempt a couple of problems, but complete solutions to these problems were available to them as a hyperlink.

A third and final section of a subunit labelled as *Practice questions* contained a number of problems at various difficulty levels and learners were expected to solve them on their own. These sections of a subunit described above were similar to the content found in a typical mathematics textbook, except that the examples were described with adult learners in mind and used meta-talk to describe procedural learning of mathematical tasks.

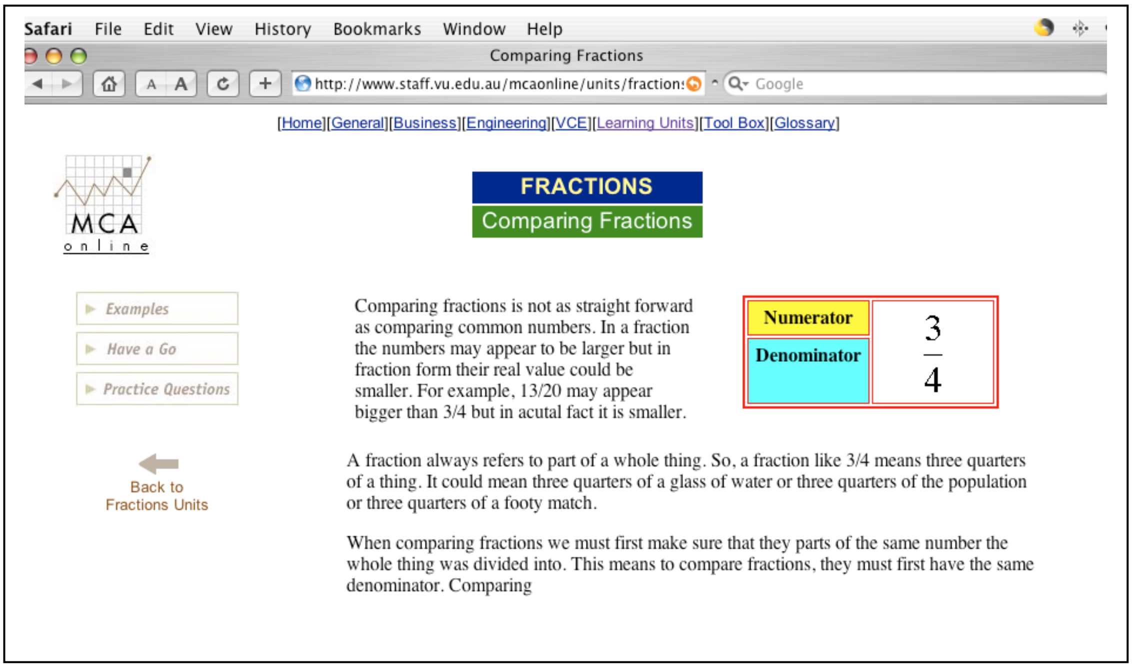

Figure 4.2. The learning unit page on the subtopic- comparing fractions.

While working on the content development of a subunit we were aware of the limitations of presenting text book like content on the web and made sure that the *examples, have a go* and *practice questions* sections of a particular learning unit were aptly supported by interactive online activities where learners could develop and practise their skills and have the opportunities to extend their conceptual learning.

4.2.4 Interactive Online Activities

The interactive online activities for learning units were selectively drawn from external websites. Some activities were particularly suited to skills practice where learners were able to attempt computer generated questions and monitor the accuracy of their responses. These activities provided learners opportunities for self paced auto corrected skills practice work. For example the learning unit on the topics of fractions provided a number of interactive skills practice activities including *Practise fractions inequalities* (Figure 4.3*), Practise reducing fractions, Practise fractions multiplication and Practise fractions simplifying*. These JavaScript based interactive activities originating from *aplusmath* website (Aplusmath.com, 1999) offered learners practice questions where learners were expected to provide a response either by selecting from a number of options as in *Practise fractions inequalities* or by typing in their answer as in *Practise* *fractions multiplications*. The automated feedback to learners' responses offered the correct solution and kept a count of correct and incorrect scores.

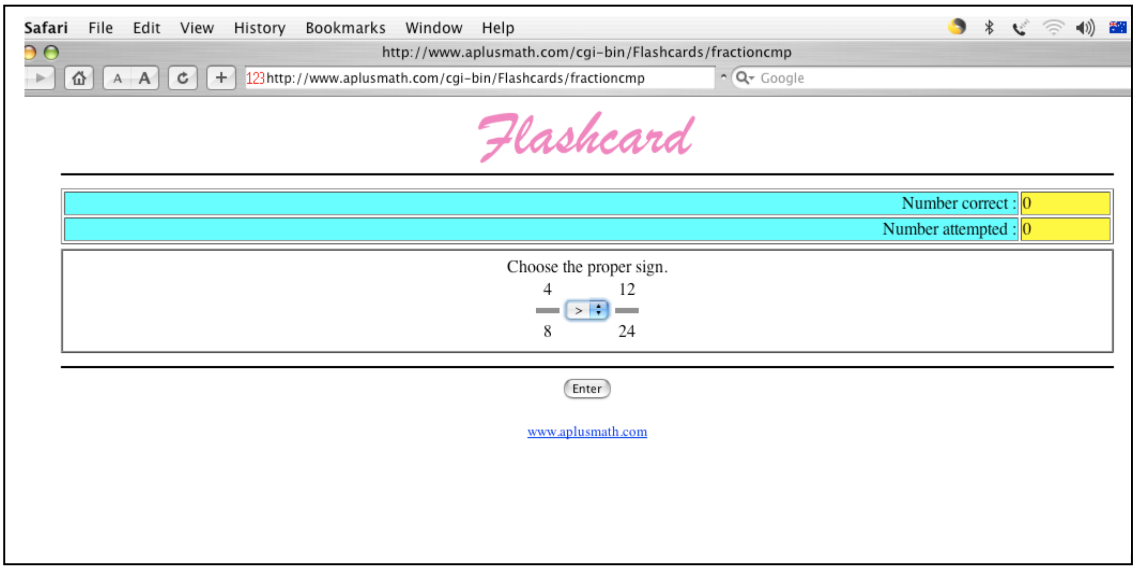

Figure 4.3. A drill and practice type interactive activity from learning unit on fractions. Source: http://www.aplusmath.com.

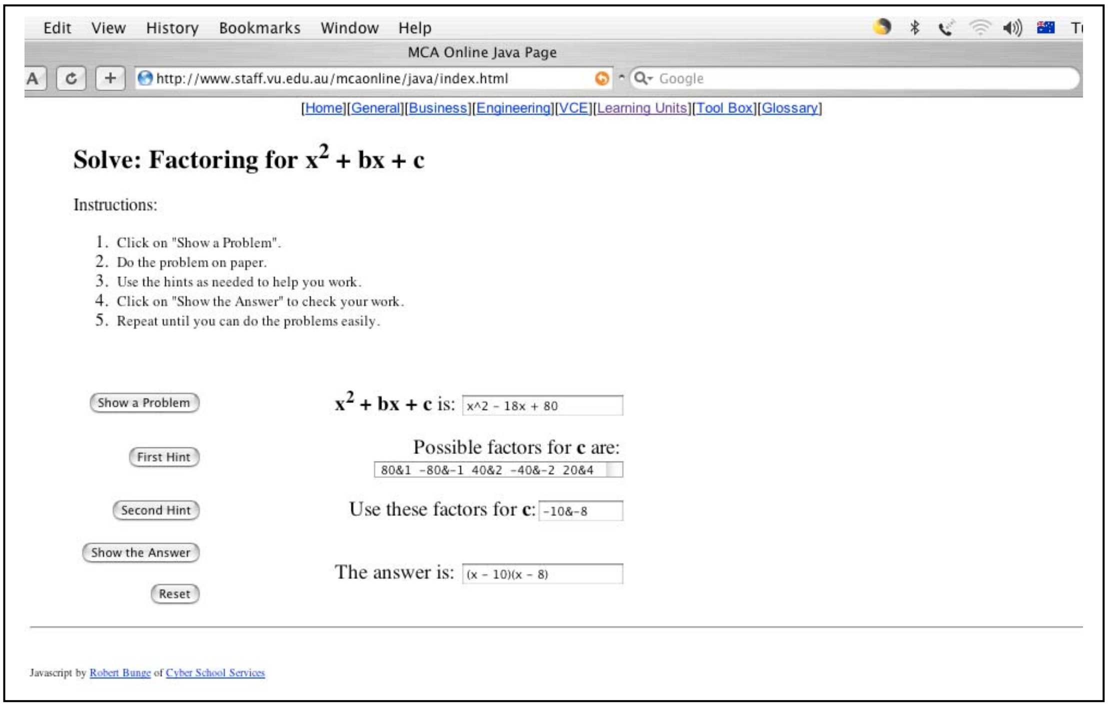

Figure 4.4. An interactive activity from algebra unit showing a step-by-step computer generated solution.
[Reproduced with permission from Robert Bunge of Cyber School Services.]

Another type of interactive activity allowed learners to observe the solution of a randomly generated problem in a step-by-step method. Learners had to click on a button to move to the next step. For example in the learning unit for Algebra *Interactive Maths Practice* link offered a range of JavaScript based activities on solving linear equations and factorisation (Figure 4.4).

We also used interactive activities where learners could input their own problems in fill-in forms and observe a step-by-step solution generated by a Common Gateway Interface (CGI) programming based automated math-solver program. These automated math-solvers used sophisticated programming to simulate a solution accompanied by explanations of each step undertaken. The interactive tools allowed learners to try their own problems to test if their solutions were similar to the ones provided by the math-solver program (4.5 and 4.6)

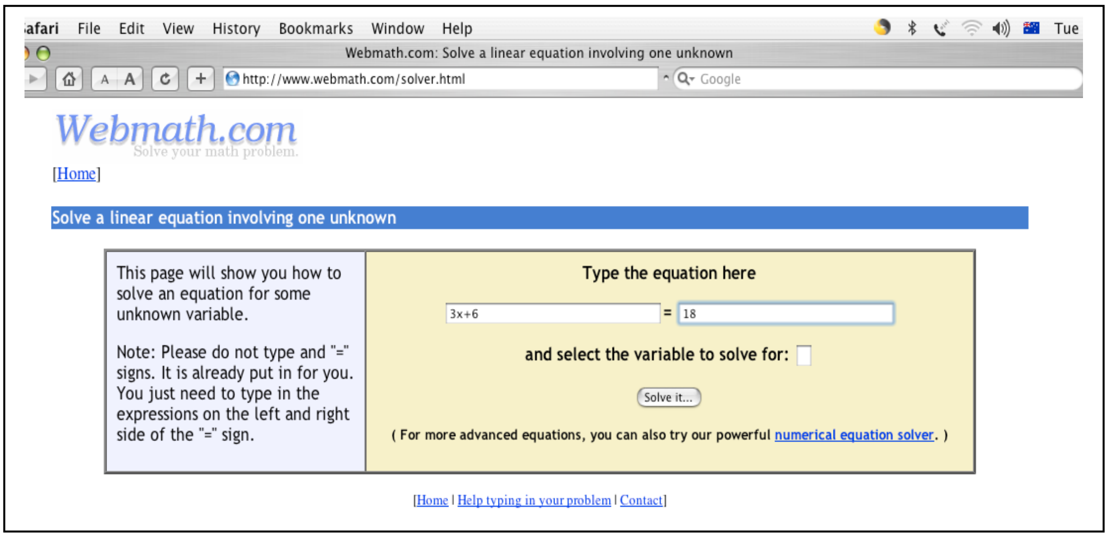

Figure 4.5. An automated maths problem solver for simple algebra equations. Source: http://www.webmath.com/solver.html.

We were also able to incorporate Java applet based exploratory interactive activities from the web into our learning units for selected topics. These exploratory activities allowed learners to manipulate a simulated activity and explore abstract relationships and concepts. For instance, an exploratory interactive activity connected to the learning unit for trigonometry provided learners with the opportunity to explore the relationship between the ratios of base, height and hypotenuse in a right angle triangle and use it to explain the ratios of sine, cosine and tangent (Figure 4.7).

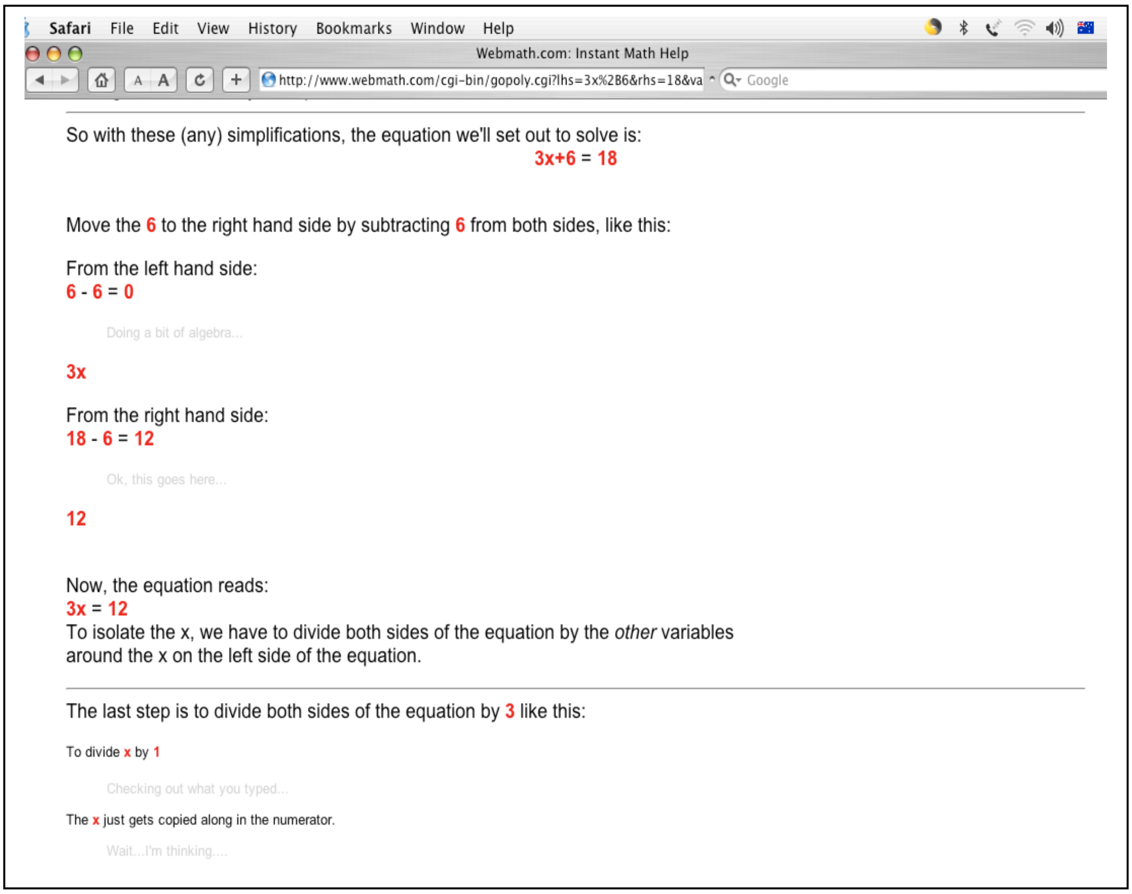

Figure 4.6. A web page showing automated step-by-step solution.
Source: http://www.webmath.com.

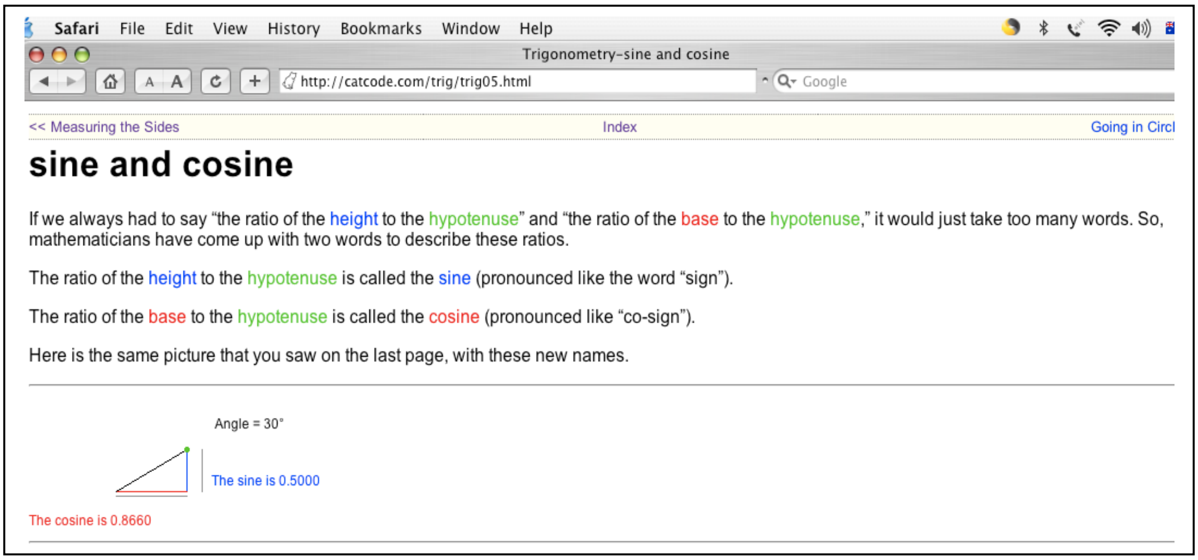

Figure 4.7. An interactive exploratory activity.
Source: http://catcode.com/trig/trig05.html.

In this activity clever use of java applet programming allowed learners to vary the size of an angle between two sticks by dragging them apart. The applet showed how changing the size of the angle between two sides of a right-angled triangle affects the ratio of sides. Computer-based interactive activities that allow learners to control and manipulate the learning environment and explore it to develop a deeper understanding of the concept being presented have consistently been favoured in educational instructional design and in mathematics education research (Ainley & Pratt, 2006; CTGV, 1992; Goos, Stillman, & Vale, 2007; Jonassen & Land, 2000; Street & Goodman, 1998).

The use of interactive activities also allowed us to incorporate authentic and real data into learning activities. The Internet has allowed various financial companies to develop and offer online tools for various numerical calculations such as home loan calculations, depreciation calculations, currency conversions, measurement unit conversions etc. Often these online tools are buried in layers of the organization's website. In the MCA online design we provided access to these tools as direct links from relevant learning unit pages. For example, from the learning unit page for the topic of Interest calculations, we provided a direct link to learners to be able to open a home loan calculator provided by a leading Australian bank.

4.2.5 Message Board and Chat

The flexibility and ease of exchanging ideas and information provided by an online communication medium was also an important element of our design plan. One of the main advantages of Internet over other forms of electronic content such as CD ROM based educational software is its distinct ability to provide access to both synchronous and asynchronous forms of communication. Email, discussion boards and chat are familiar forms of communication tools for the Internet. In designing the MCA online learning environment we were aiming to create opportunities of both teacher- learner communication as well as learner- learner communication. We also wanted to build a facility which would allow dedicated real time online chat where regular online chat sessions led by a mathematics teacher can offer assistance to learners who were located remotely or were unable to access our MLC facility during its operating hours.

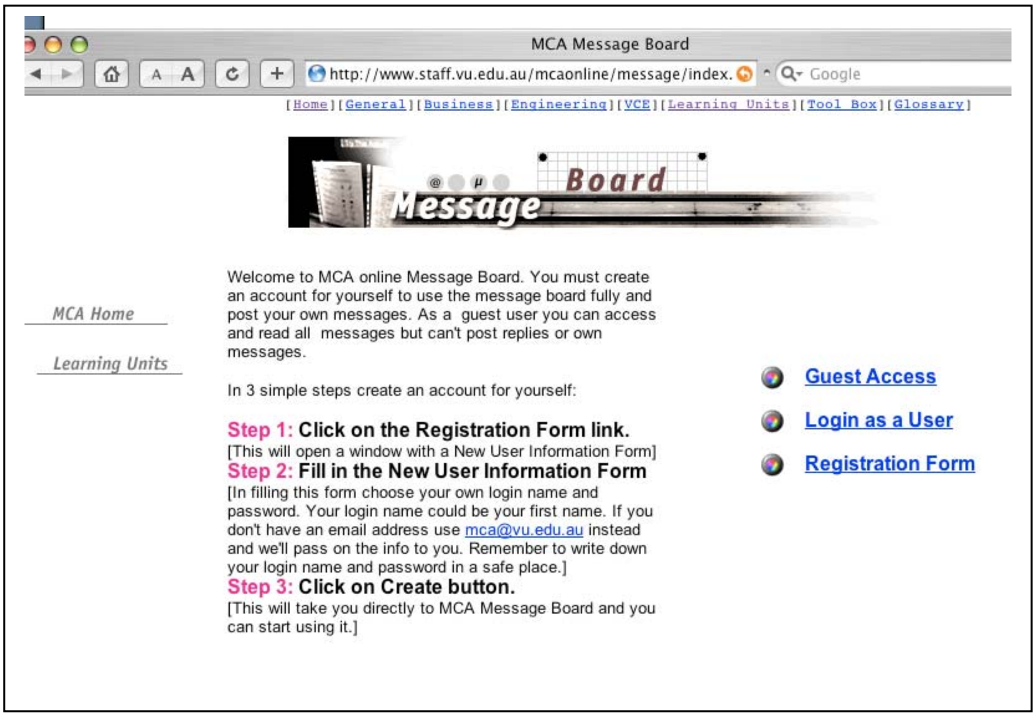

Figure 4.8. The message board entry web page.

Our university had a site licence for a commercially available online communication platform known as WebBoard. This communication platform allowed both synchronous and asynchronous communication to take place from the same interface but in our design we planned to keep the chat system separate from the message board area. By keeping the chat system accessible from a separate web page we made it simpler for students to access the chat facility.

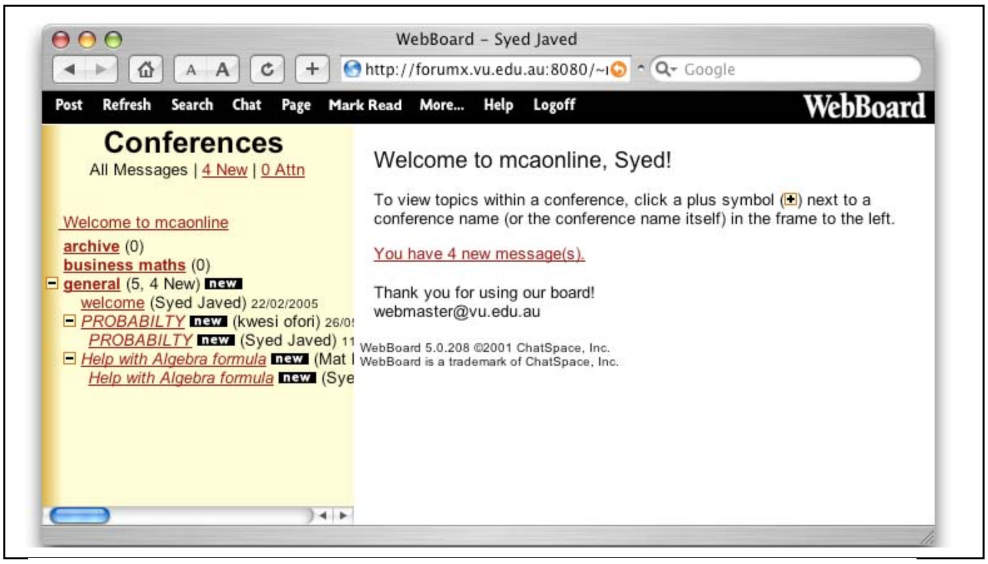

Figure 4.9. The message board interface.

The asynchronous feature was accessible from a message board link from the MCA online home page. It was accessible to all visitors to the MCA online website with a guest account access without the need of a user ID or password (Figure 4.8). However, only registered users could post new messages and reply to previously posted messages. The message board link took users to a message board web page (Figure 4.9). This web page provided information about how to use this message board and links for guest access, registered users access and a direct link to registration form for new users.

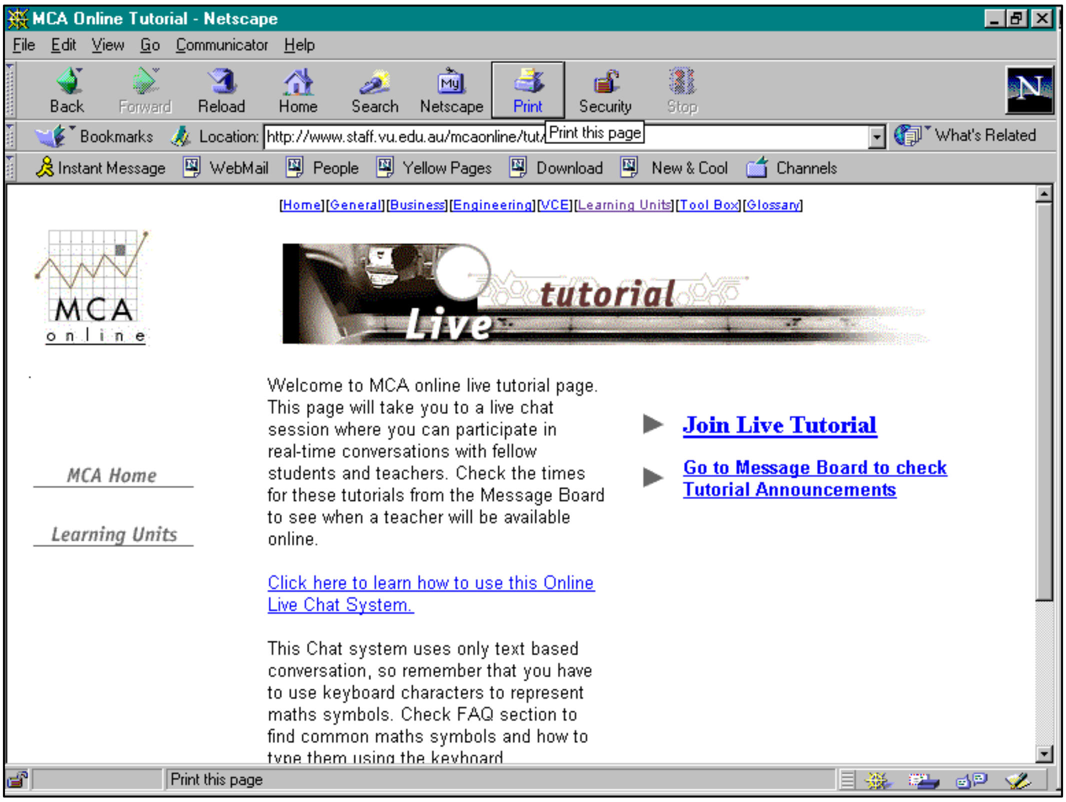

Figure 4.10. The live tutorial web page for accessing chat.

An online chat facility was provided using a separate link from the main home page. This chat facility was labelled as online tutorials. The online tutorial button was linked to a web page with details about how to use the live online tutorials facility (Figure 4.10). A help page to show users how to use this chat program showed screenshots with instructions. This page had a “join live tutorial” link that opened a separate chat window when clicked. Announcements about the live chat sessions were posted on the message board and a link to these announcements was provided on the live tutorial web page. This java applet based synchronous chat program was limited to text-based communication only and sharing of graphics or drawing of line images was not possible.

In addition to learning units, interactive activities and communication facilities the MCA Online website also provided a toolbox and a glossary sections. The toolbox section contained resources commonly needed in mathematics learning. A JavaScript based online scientific calculator and a units conversion calculator was included in the toolbox along with quick reference pages on commonly used mathematics formulas and symbols. The toolbox also included links to basic mathematics, statistics, calculus and financial terms glossaries. The main purpose of the toolbox section was to provide self-help mathematics tools to learners.

The MCA online website also included discipline specific resources for Business, Engineering, VCE and general mathematics in four separate sections on the website. Each section was directly accessible from the homepage of the MCA online website and contained resources such as module details, archives of past question papers and solutions, booklist and links to a selection of learning units relevant to that particular discipline. As the initial purpose of MCA online website was to provide learning support to students undertaking vocational and general mathematics courses, we included in our design many useful resources sought by students undertaking mathematics modules from these disciplines. The project team contacted teachers from various departments and collected module information, course notes and past test papers. Digital copies of these resources were created by word-processing and scanning.

4.2.6 Issues and Concerns

As a designer, I was aware of the problems associated with website links that go out of date and users receive an error message when they try to use the link. Firstly, we tried to develop most of our content locally and relied on external links only for live data, simulations and java based interactive content that was beyond our skills and scope to produce. In order to overcome the ‘broken links problem’ I took the initiative to seek permissions from original authors of selected JavaScript programs to allow me to host their scripts on my local web server. In this way I managed to design some online tools and activities such as the scientific calculator or the interactive algebra exercises without the risk of broken web links. Also, regular checks were made to ensure that all links from the MCA Online website were current and active.

Finding and reviewing websites with online mathematics activities was an important task for the project team and we shared our findings and reviewed useful sites for possible inclusion to relevant sections of the MCA Online website. This review and revise cycle was an essential step for keeping external online links working and ensured regular updating of broken web links from the MCA Online website. For example one of the websites hosted by Webmath.com was taken over by a commercial company and links to online activities located on this website were lost due to authentication requirements of the commercial company. We were disappointed to lose free access to these online activities and responded by replacing these links with new links from our directory of reviewed websites.

One of the major challenges in creating a website for mathematics learning was the difficulty of writing mathematical symbols and expressions. Although Microsoft Equation Editor offered a solution for writing common mathematical terms in a word processing document, it was not possible to copy and paste these mathematical expressions into a web page editor. As mathematics symbols and expressions were not supported by HTML code, it was not possible to present mathematical expressions on the web using text or ASCII codes. The only solution available at the time was insertion of mathematical expressions as a graphical element on the web page. We acquired the MathType software that allowed writing of mathematics expressions and saved them as GIF images. These GIF images of mathematical expressions could be embedded in a web document with some tweaking required for text and image alignment on the page. In this way, the MCA Online was able to overcome the difficulty of writing mathematics for the web with the use of MathType software.

4.3 Enactment

The successful design and construction of the MCA Online website was a significant achievement for the project team and added a new dimension to the operations of our department’s Maths Learning Centre (MLC). After an initial phase of testing, proof-reading and editing the new learning environment was put to immediate use with students attending the MLC. During the first semester of 2000, in order to introduce this new learning environment to mathematics teachers and their classes in the TAFE, I developed a module (manual) that explained different features of the MCA Online and provided simple exercises to introduce the learning environment to learners (see Appendix 8).

In the following semester the MCA online environment was piloted with a number of classes and feedback from students and teachers was collected. This process led to further refinement of the product (MCA Online website) and identification of issues related to the use of such an environment to support mathematics learning. In addition to the introduction of the MCA Online website to the vocational mathematics classes as a supporting resource, I implemented it in my CGEA certificate II class in a blended learning format and noted the pros and cons of implementing it as an integrated learning resource with the traditional curriculum. In the following sections I will describe how the MCA online implementation in three different modes led to its continuous refinement and tested the conjectures held at the beginning of the development of this learning environment.

4.3.1 MCA Online in the Maths Learning Centre

The Maths Learning Centre (MLC) operated within my department as a drop-in centre. During morning hours the MLC was used as a classroom to teach regular mathematics classes to general education students and during afternoons it served as a drop in centre for all other students. Usually, students from VCE, business and engineering branches would drop in with their problems in mathematics, or sometimes teachers from these departments would recommend a student who would seek help from the MLC on a regular basis. A mathematics teacher was always available in the MLC but at times, it became difficult to attend to the needs of several students at the same time. The MLC teachers prepared relevant practice work and used mathematics worksheets to keep students engaged so that their time could be used more efficiently in helping all students.

The MLC also had five networked computers and these computers served students computing needs in mathematics. The computers had programs such as Microsoft Excel, Maths Blaster, Measuring Up, Geometer's Sketchpad and many freeware skills practice mathematics programs downloaded from the Internet. Once the MCA online website was launched, these computers were set to open the MCA online website as their default home page. The availability of the MCA online website in the MLC helped in two ways. It helped teachers working in the Centre by providing them instant access to worked examples, exercises and activities that could be easily printed and given to students for extension work. Secondly, it served as an important learning resource for students especially with the interactive auto-correcting exercises. Students waiting for assistance or needing extra practice were directed to these online exercises to allow the MLC teacher to share their time with more students. With the help of auto-correcting practice exercises students required less direct teacher attention.

As the MLC was the first educational setting where the MCA Online website was being used, it served as a field-testing ground for the refinement of the new learning environment. It allowed for a closer scrutiny of the MCA online content and links and errors noticed were rectified on a regular basis. The MLC procedures allowed for documentation of students' particular use of MLC facilities and teachers were able to record any errors or difficulties experienced with the online learning environment. Observations of students and teachers using the MCA Online website showed that users with little or no experience of computer usage found it difficult to navigate their way around and often did not see that there was more content available on the screen and required their use of the scrolling bar. Many students were unfamiliar with the use of websites as interactive learning interfaces and required teacher guidance to show them how different buttons and selections worked in the online environment. Students also had to learn equivalent ASCII keys for writing mathematics expressions and symbols on the screen. Another important advantage of using MCA Online website in the MLC was that many new and useful links were added to the online learning environment. The use of MCA online within the MLC program helped in identifying new links and revising existing links according to the needs of students. As far as the design of the learning environment was concerned the structure of learning units contained a static part in terms of *Examples*, *Have a go* and *Practice questions* sections where learning content could not be changed, but the links to relevant websites belonging to individual learning units could be continuously revised according to needs of students, discovery of new online tools and activities, and links becoming outdated. One feature of the MCA Online website that remained unused during its use in the MLC was its communication feature. It appears that because the website was not included in the classroom learning in a structured way, the students did not feel the relevance or the need for using the message board or the chat facility.

4.3.2 MCA Online Use Promoted with a Module

After introducing the MCA Online environment in the MLC we moved to extend its usage beyond MLC and planned to use a pro-active strategy to promote this online learning environment in mainstream vocational mathematics courses. We knew that it was important to familiarise teachers and students with this new learning environment before they would be interested in trying a new and computer based medium of concurrent support and learning. After consultations with mathematics teachers and program managers of interested departments it was proposed that if we developed a short non credit module to introduce the MCA online services and resources, general and vocational mathematics teachers will be willing to recommend their students to take this non credit flexible delivery module to help them improve their mathematics. We also knew that when the online learning medium is introduced in a structured way, we would be able to test our conjectures with more confidence and evaluate its use. Consequently, a short module was written to serve as an induction manual and contained activities and exercises to familiarise learners to various tools and resources available from the MCA online website (Appendix 8). The design of the module was based on an assumption that when teachers and students have become familiar with using the MCA Online tools and resources they would be more willing to explore the MCA Online website to seek assistance with their course related mathematics needs. With this purpose in mind the module was divided into four sections – *communicating online, working with maths problems, using tools and references* and *using online symbols*. The module aimed to achieve the following learning outcomes:

- Communicate using MCA online Message Board
- Identify appropriate paths for solving problems at MCA Online
- Find and use relevant maths tools and resources

- Become familiar with online maths symbols and expressions

The *Communicating Online* section of the module focussed on message board activities and explained the process for registering as a new user, reading and posting messages and joining for a live chat. The section contained online activities where learners were given step-by-step instructions for completing a given task such as post a new message on the message board. The section on *Working with Maths Problems* explained the contents and structure of a learning unit and how links to online resources from the web offered practice activities for a selected learning unit. This section also contained hands-on activities where learners had to complete a given task of following a learning unit to understand basic maths concepts and locate answers to selected problems at the Ask Dr Math archives of questions and answers. The third section of the module concentrated on *Using Tools and Resources* and explained how to use online calculators and glossaries. Four different activities guided learners how to use different online tools for maths calculations. The final section of the module focussed on *Using Online Symbols* provided learners with an overview of symbols used in writing mathematics in an online environment. This section also contained activities where learners had to carry out mathematical calculations and write symbols and expressions in an online form.

During the second semester, 140 students enrolled in Electronic Engineering, Business and Marketing, Women’s Education, Language Studies and Adult Basic Education programs participated in this flexible delivery module which aimed at equipping them with the necessary skills to use the MCA Online learning environment to support their course related mathematics learning needs. With assistance from mathematics teachers from these departments I conducted workshops to introduce the MCA online website using selected activities from the induction module. A copy of the induction module was given to each participant and they were advised to go through all activities contained therein in their own time. These face-to-face workshops allowed learners to become familiar with the MCA online environment and the module expected students to complete a number of tasks in their own time during the next few weeks. We especially wanted students to use our communication system to seek mathematics help and share their learning. The conduct of these MCA Online workshops was also aimed at providing a professional development opportunity to teachers and build their confidence in using new learning technologies to enhance their classroom based teaching and allay the fear that increased use of online technology is intended to replace traditional classroom contact with students. The workshops were conducted as a team effort with the class mathematics teacher and allowed him/her to observe and participate in MCA online learning activities.

All students participating in the workshops and undertaking the induction module were asked to respond to a questionnaire (Appendix 9) four weeks after the initial workshop. In addition, classroom observations and postings on the message board were used to evaluate the pattern of access and usage by students. Any content and design issues such as incorrect answers or broken web links were immediately acted upon to refine the design of the learning environment. The promotion of MCA Online website using an induction module also provided opportunities for teachers to reflect on the content, design and students' usage of the MCA Online website. Teachers provided feedback via emails and a response sheet. Comments from the email and response sheets were further clarified in face-to-face informal interviews. The trial of the MCA Online website with mainstream mathematics classes revealed a number of interesting issues in relation to implementing an online learning support and teachers' attitude and perceptions towards such an innovation.

A primarily logistical issue in using online learning support within classroom-based mathematics was the fact that most mathematics classes were held in traditional classrooms where no networked computers were available. In order to conduct our MCA Online induction workshops we had to arrange and move to a computer laboratory to enable access to the MCA Online website. However, this was only a temporary arrangement and classes reverted to their normal locations after the workshop sessions. Many teachers and students reported that this lack of access to networked computers in mathematics classes could have constrained their use of this new learning environment.

All students enrolled in the university were provided with an email account but many continued to use their hotmail or similar email accounts. The data from the students' questionnaire confirmed that more than 70% of them regularly checked their email. Nearly 30% of these claimed to check their email on a daily basis and at least 40% said that they log on to their email accounts at least once a week. These trends suggested that most students were becoming familiar with online services but may not have access to these services on a regular basis. Many students also revealed that they relied on university computers to access their email accounts. The same trend was noticed on the MCA Online message board service where most students posted messages only from the university computers. Access to network computers at times convenient to students appeared to be a significant factor in the use of the MCA Online environment from outside class hours. From this experience it was clear that access to network computers is crucial in the success of online-based flexible learning methods.

More than 70% students reported that they found MCA's resources useful for their mathematics learning needs. Nearly 50% found these resources very useful whereas 30% found them to be sometimes useful (Figure 4.11). About 10% of the students were still undecided. In response to a related item on the questionnaire (item 9 Appendix 9) many students reported that they needed more time to use these services to truly assess its usefulness.

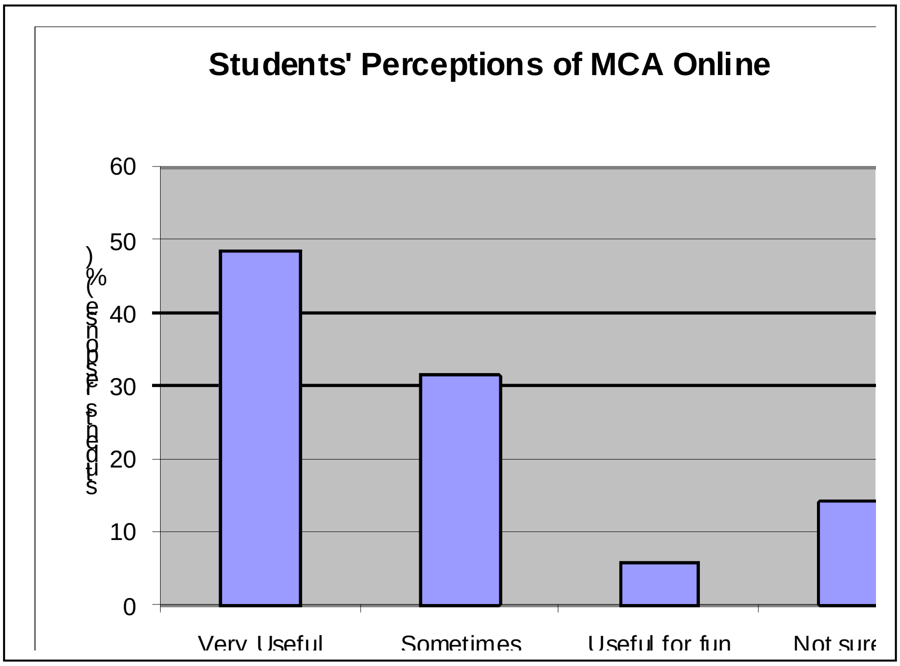

Figure 4.11. Students' perception of MCA Online Environment.

Students' approval and willingness to adapt to the new methodology of online facilitated mathematics learning was an encouraging signal showing that students were willing to take advantage of this new learning environment if appropriate access and training structures were put in place to optimise learning opportunities offered via the MCA online environment.

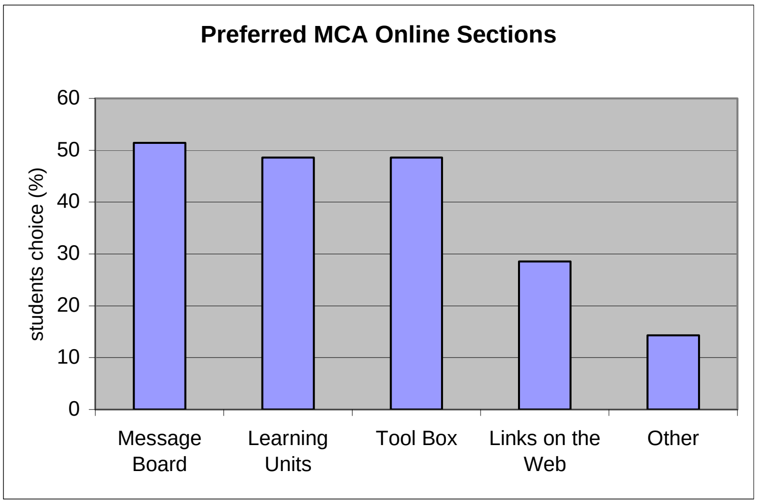

Figure 4.12. Students' preferred sections of MCA Online environment.

According to students' responses for the question on what sections of the MCA Online website they were likely to use in future (Figure 4.12), almost 50% students agreed that they would like to use the *Message Board*, *Learning Units* and *Toolbox* sections in future. These responses suggested that electronic communication and feedback were valued parts of online learning environments and students preferred content supported with communication and feedback services.

However, in practice students' use of the *Message Board* and *Live Chat* sessions was limited mainly to in-class use during the workshops and training sessions. Contrary to our expectations, students did not take up the challenge of posting messages to seek assistance and hardly used the message board to post messages. In terms of chat, during the whole semester four invitations to live tutorial sessions via chat were posted on the message board but there was no response to these invitations and no one turned up for online chat. The problems with using chat sessions to conduct mathematics tutoring had become obvious even during the workshop sessions as students found it difficult to articulate mathematics symbols and expressions in a chat environment.

It would be incorrect to assume that students did not have adequate technical skills to participate in online communication because the same students were using email and social chat programs such as MSN Messenger regularly and the university had to place a ban on unauthorized use of chat programs in computer labs. Possible reasons for this lack of use of online communication may lie with issues of access to the Internet and difficulty of writing mathematics on the computer (Gadanidis, Gadanidis, & Schindler, 2003; Smith & Ferguson, 2005). But an equally if not more significant reason could lie in the fact that students had no motivation to use the online communication because their mainstream mathematics subject which counted towards their results had no connection with using the online communication facility.

This lack of activity on the message board and chat sessions indicated that simply making an online service available to students does not necessarily motivate them to start using it for their needs. Perhaps students needed to see a direct connection between their classroom work, course assessment requirements and the use of online facilities. It became clear that TAFE students generally were not yet prepared to use online facilities to independently seek support in mathematics learning.

Another issue related to the use of MCA Online environment was that apart from the message board services the system did not allow any other monitoring of usage. For example there was no electronic monitoring or feedback on students' usage of sections of the learning environment other than the message board and chat. Informal feedback from teachers and occasional emails provided an indication that students (and teachers) were pleased to have access to this learning environment and made use of many of its learning units sections. For example, an email from a teacher in the electro-technology department confirmed the apparent usefulness of our MCA online environment as he reported that his students were making regular use of the content and links available from the MCA Online website and his own department's website had made links to MCA Online pages to help students access the contents easily. In an email he wrote:

> *This is just a short email to give thanks to the people who put together the MCA Online site. We in the Electro-technology have numerous links to your site from our own online material and our students (around 400 a year) use your site extensively and feedback we get from students is always extremely positive with many*

commenting on how well the site has been put together and how much help it has given them with their maths.

It is good to see areas within (university) that have actually done something worthwhile with online material and not simply talk about "investigating the possibilities of doing something with it in the future.

Regards,
Program Manager

Formal feedback using a questionnaire (Appendix 10) from teachers involved in trialling the MCA Online learning environment indicated that they were impressed by the look and feel of the website. Teachers generally agreed that the instructions were clear, graphics were good and navigation was easy. They found the website easy to manage in terms of moving from one section to another and returning to home page from any location. The teachers did not like the chat facility and found it confusing and limiting for instructional purposes. Most teachers lacked familiarity with the message board postings and the discourse of threaded discussions. In contrast, students demonstrated a better understanding and fluency in the use of both the message board and chat facilities.

Mathematics teachers from the general education courses found that the content of MCA Online was very relevant to their courses and were generally very pleased with the interactive online activities in mathematics. There were comments about adding special features. For example one teacher said that,*" I would like more units in ESL maths, perhaps an ESL dictionary".* A VCE teacher commented that, *"I would like more depth – extend the trigonometry range".* In vocational areas such as business mathematics, the teachers were keen to offer additional learning opportunities via the MCA Online website but noticed that any sustained use of online services would require more planning of content and assessment strategies. They confirmed that the use of online resources in teaching would make their content more realistic and relevant for students.

During the trials of the MCA Online environment it also became evident that teachers were willing to use online learning environments but needed professional development both in terms of technical skills and online teaching and learning strategies. Most TAFE students taking part in MCA Online program were able to access and interact with the online environment but required some guidance in using facilities such as interactive activities and online communication. They also needed instructions and practice in using special symbols to write mathematical expressions on the web.

4.3.3 MCA Online in Classroom

While the MCA Online website was being promoted using a MCA Online induction module, I took a general mathematics class for the CGEA certificate II with a group of 12 students. These students were doing an adult education course and nearly half the class comprised of students in their late teens who had left school early. I took the opportunity to trial the MCA Online environment with this group to explore the issues and possibilities in using it in a blended learning format. I had a 3-hour class per week where I arranged to have a two-hour session in a traditional classroom and moved to a computer lab close by for the final hour. Students would start with a face-to-face session in the morning and do a mathematics topic using pen and paper activities and tasks. After about 90 minutes the class would take a short break and return in the computer lab for the MCA Online supported learning. In previous years I had faced difficulties in keeping the youth members of the class motivated enough to maintain their focus on learning during a 3-hour class. This arrangement of a two-hour traditional and one-hour computer based class aimed at providing them a variety in teaching method.

In a typical class I would start a mathematics topic with a reference to some everyday event and then build the context for learning with the help of students' responses. This would be followed up with an explanation of the mathematical concept with illustrations and examples. Often the examples would be solved on the whiteboard with students' responses and feedback leading to the next stage of solution. For example, a topic on calculations and use of percentages may start with issues of discount sales in everyday life and introduce the concept of interest rate calculations. The two-hour class time would be used in reviewing and doing practical problems on the whiteboard and in students' exercise books. It may be followed up by a group activity using newspapers or some other hands-on problem solving before the class interval. When the group reconvenes in the computer lab, the students would be shown the MCA section on percentages and would do interactive online exercises on calculating discount prices or working on percentage skills. Later students would be asked to investigate the cost of a home loan using an interactive online calculator from a link from the Learning Unit on percentages. Sometimes I used the Message Board to post the problem to be solved and asked students to post their solutions back using the message board.

In this way, blending classroom learning on a topic with relevant online activities allowed me to extend the learning for both drill and practice and also for experiential learning and problem solving tasks. The continuous use of the MCA Online environment during the semester with the same group of students allowed me to make closer observations of students' use of selected online resources and gain an understanding of issues of teaching and learning mathematics with the help of web-based learning resources.

The experience of using the MCA Online environment in a blended teaching model indicated that students' participation in learning improves when they use MCA Online with their regular classroom work. Notes from my teacher's diary indicate that more tasks were completed by this group of students. In addition, the attendance records also showed that this group had the lowest drop- out rate for the year compared with previous two years' groups and many times students stayed back in class longer to continue to work on their problems on the computer. Direct links to interactive online activities from the MCA Online website allowed students to navigate easily and address the issue of being lost on the web and not being able to find the site that the teacher wants them to use.

Since the online learning environment did not monitor students' access and use by an authentication (login) process, it was not possible to know out-of-class use of the website by this group of students. In terms of using the communication system, students used the Message Board more frequently than in the trials using the MCA module but there were very few postings initiated by students. Most postings were in response to the teacher's problem task. The Online chat facility was not used, as the class did not seem interested in using it to discuss mathematics. This blended model of classroom use of MCA online learning environment showed a positive response from students in terms of their engagement and participation in learning activities. It also encouraged me to explore the affect of using MCA Online environment on students' understanding and achievement in mathematics more closely. I also became interested in monitoring learners' engagement with the online medium more closely because it promised to show the details of students' access and use of the MCA Online learning environment and how their performance and attitude towards mathematics changed by its use.

4.4 Review and Redesign

The implementation of MCA Online website during a period of one year where it was promoted and trialled using a module, embedded in the MLC as a computer based learning resource and blended in a mathematics classroom provided an opportunity to continually refine the content and design. Feedback from students and teachers and observation of classroom use of MCA online website tested our conjectures about the design and use of this environment.

Conjecture 1: Navigational scaffolding would allow students to focus on a particular learning path and avoid distractions resulting from browsing external websites

The assumptions about the design of this learning environment and the apparent value of scaffolding students' learning using links to interactive online activities appeared to be true (Gerber & Shuell, 1998). Data from students' and teachers' questionnaires and classroom observations indicated that navigation on the website was clear and easy. Students were able to use external links to interactive online activities successfully without being lost or distracted to other information on the web. Although the website kept a record of Message Board postings, it did not monitor students' use of other sections and areas of the website. The website also could not show the pattern of student access to the learning environment from outside class hours. These observations confirmed our view that navigational scaffolding and direct links to interactive online activities assist in students' access and use of the online learning environments.

Conjecture 2: Interactive online activities providing immediate feedback to learners would be able to engage students' attention for longer and help in building students' understanding and use of mathematical concepts

The links to interactive online activities that provided immediate feedback to learners were well received by both teachers and students. Many online links allowed use of authentic learning experiences and real time data in classroom problem solving tasks (Bransford, 1990; Hoyles, Noss, & Kent, 2004). As anticipated in our design conjectures these interactive online learning activities were popular amongst students and appeared to enhance their confidence and understanding, but there was no measure used to determine a cause and effect association. There were some difficulties, as expected, in writing mathematics symbols and expressions for online tasks, but with teacher's guidance students were able to adapt to this new way of writing mathematics. These findings encouraged us to plan a quasi-experimental design in the next cycle of the study to look for empirical evidence of improvement in achievement scores.

Conjecture 3: Communication tools such as a discussion board and live chat would be able to extend students' access to the teacher's guidance and promote a culture where students could help each other in learning

The MCA Online environment provided a means of asynchronous communication in the form of a *Message Board* and a synchronous communication facility as *Live Chat*, but both these systems were underused during the implementation. Technically, the communication platform was quite stable and did not require any special plug-ins or browser setting. But, students' use of the *Message Board* remained confined to postings in response to teachers' questions. The chat facility remained almost totally unused because both teachers and students did not show any enthusiasm for using it to talk about mathematics. The minimal use of *Live Chat* could be attributed to inherent difficulties in writing mathematics expressions on computers, the nature of learning and TAFE teachers' reluctance to use chat systems. In terms of message board postings, the lack of postings may also be attributed to the teachers' skills or lack thereof in soliciting and encouraging online dialogue. In our observations mathematics as a subject appeared less conducive to online community building through threaded discussions (Smith & Ferguson, 2005). These finding led us to abandon the chat facility for the next cycle of this study and allowed us to focus of asynchronous communication through a discussion board facility. The refinement in our conjecture about the use of online communication led us to assume that when asynchronous communication is limited to a small community and a specific context, its use would be more productive in terms of students' participation, access and use.

Conjecture 4: Making discipline specific learning resources available through a website would encourage mathematics teachers to direct their students to use these resources and use this website as a reference in their regular face to face classes

The conjecture about providing discipline specific content and links on the MCA Online website so teachers from these disciplines would be more willing to integrate the online learning environment in their classroom teaching did not materialise into practice as we found that many mathematics teachers did not have necessary computer skills to confidently integrate such an environment in their classroom teaching. However, there was an acknowledgement by teachers of the value of the MCA Online website in supporting mathematics learning. In addition, some departments also commented that the content on the MCA Online website was limited to basic mathematics learning and as such could only be useful as a refresher. However, as shown by the comments made by the Electro-technology department cited earlier in Section 4.3.2, it was possible to integrate resources provided by the MCA Online environment in a discipline specific learning website or platform. These observations led us to refine our conjecture regarding the effectiveness and use of an open access online learning environment to support mathematics learning in vocational education programs. As envisaged in design-based research cycle (Figure 3.1) we proposed a redesigned and customised online learning environment that used the course content of particular vocational courses in developing the online learning environment. Our refined conjecture contended that this model of integrating and blending MCA Online resources in vocational education courses could serve the mathematics support function while maintaining the context specific learning of a vocational or trade based teaching of mathematics.

4.5 Conclusion

This chapter has provided a comprehensive account of the context, conjectures and the process concerned with the design and implementation of an online learning environment in mathematics as the first cycle of this design-based study. It has shown that the study emerged from the need of a TAFE department to improve its ability to support students from vocational education courses in their mathematics learning. A web-based learning environment, MCA Online, was developed in collaboration with two mathematics teachers to complement the learning support provided by a Maths Learning Centre in the department. In order to make mathematics teachers and students familiar with this new learning environment an induction module was written and workshops were held in five departments within the TAFE sector of the University. The MCA Online environment was also used in the Maths Learning Centre and in a blended learning format in a general mathematics class taught by the author.

The design, the development and the enactment process in the first cycle provided useful insights into building and using a web-based learning environment in mathematics classes. The design process brought to our attention a range of web-based interactive learning resources but also exposed the problems of writing mathematics content for the web-based environment. It also made it clear that mathematics teachers needed additional computer training in order to use the online learning environment effectively.

The implementation of the MCA Online website in various settings and our observations regarding its usability and effectiveness in attracting students to use it as a self directed learning environment led us to refine our conjectures and think about revising our approach to supporting students learning. The fact that students doing mainstream mathematics subjects did not respond to the services offered by the MCA Online independently, as tentatively anticipated in our conjectures, confirmed the view that merely making technology based services available to students would not result in their appropriate and effective use. The implementation of the MCA Online website in the first cycle of this study indicated the potential for its effective use in a blended environment where face-to-face teaching was supported and extended with the use of an online learning environment. These findings led to the second cycle of this design experiment where a systematic study of blended online learning was conducted by supporting and extending face-to-face classroom based teaching of a business mathematics module with an online environment based on MCA online resources.

Chapter 5: Research Cycle 2

5.1 Introduction

This chapter is an account of the second research cycle of this study where the MCA Online learning environment developed in the first cycle was customised and used in the teaching of a mathematics module for a business and marketing course. The WebCT delivery platform was used to present the customised MCA Online learning environment. Using a blended learning approach students were taught on-campus where face-to-face teaching was complemented with online activities. In Section 5.2 of this chapter I have presented the context of the second cycle of this study in terms of the description of the course, the profile of students attempting the course and the mathematics teacher's approach towards teaching the business mathematics module. Section 5.3 provides details of the conjectures related to this cycle of research and the process of designing the WebCT website for the course. This section also shows how the MCA Online resources were built into this new website for the module. In Section 5.4 I have given a detailed account of the enactment stage describing the mathematics lessons taught in terms of teaching and assessment methods and reflections on the use of online activities during the lesson. Given the nature and scope of descriptions provided in this chapter, the analysis phase of this research cycle is presented as a separate chapter (Chapter 6).

Evidence from the experience of designing and implementing the MCA Online website during the first research cycle indicated that a generic open ended online learning environment to support mathematics learning had limited appeal to students enrolled in mainstream vocational courses. We discovered that in order for students to make effective use of online resources in their learning these resources had to be situated in the context of specific vocational content.

In addition, mainstream TAFE mathematics teachers also appeared to be slow in responding to online developments and how online resources could impact their teaching practice. During the first research cycle many mathematics teachers were unsure about the skills and effort needed in implementing web-supported teaching.

Furthermore, during the first cycle of the study we found out that the design of the MCA website did not allow us to track students' use and as a consequence we were unable to confirm if students were actually accessing and using the online resources. Limited classroom observation and postings records on the discussion board were the only sources of any empirical evidence for students' engagement with the online environment.

The observations and findings from the first cycle led us to conclude that the online learning environment needed to be closely aligned to the vocational course content in order to engage students and teachers in its use, and enhance and support mathematics learning effectively. Consequently, the second cycle of this study focussed on an in-situ implementation where online learning could be customised to suit a particular vocational context and our conjectures about design and learning could be explored with the help of a systematic process of data collection and analysis.

5.2 Context

During the development of the MCA Online website in the first cycle of this study I had come into contact with a number of mathematics teachers from mainstream vocational courses. These teachers provided useful information, support and trial sites for the implementation of the MCA Online website and the induction module during the first cycle. Cathy (a pseudonym), who had been teaching mathematics modules for the business and international trade courses and had also been involved in the development of the MCA Online website as an advisory group member, showed an interest in using this website with her mathematics class. One of her mathematics classes had previously participated in the induction training for the MCA Online website during the first cycle, but she had noted that her students did not show interest in using the MCA Online website mainly due to the generic nature of the content on the website.

From her experience of teaching the Introduction to Business Mathematics module for a number of years Cathy claimed that customising learning activities and resources available from the MCA Online website to suit the context of her course could benefit her class in two ways. Firstly, by including online activities in her teaching she would be able to make mathematics learning more interesting, relevant and appealing to students who love to work on computers. Secondly, by having access to learning activities and resources available from the MCA Online website students would be able to brush up on important basic skills necessary for doing her mathematics module. Although the prerequisite entry qualification for this course was listed as completion of a Year 12 secondary school certificate, students with little or no mathematics education were also able to gain admission to the course. Cathy was in charge of teaching mathematics modules to a number of groups studying business and marketing courses in the TAFE division and she was concerned about the drop out rate from mathematics classes. Cathy and I shared these concerns and were aware of the potential usefulness of the MCA Online website for these students but results of the trials in the first research cycle had shown that students needed to see the relevance of online activities in the context of their course. They were not prepared to use the online learning environment to seek support and brush up their skills independently.

Studies have shown that open ended access to innovative learning environments or tools is not enough to engage learners and important contextual preconditions need to be taken into account to ensure effective use by learners (Hoadley, 2004; Hsi, 1998). Emerging research on online learning in the VET sector indicated that mixed mode learning or blended online learning appeared to be increasingly favoured by the teachers and learners (Brown, 2003; Fisher, 2003; Franklin & Peat, 2001) in contrast with totally online delivery, where despite a large number of modules being available in the online format, the uptake of online learning remained relatively small (Hill et al., 2003).

5.2.1 The VET Course

The selected mathematics module was part of a diploma course in international trade offered by the Department of Management and Marketing. Like most other business courses, the Diploma in Marketing (International Trade) course was also based on industry endorsed competency standards ensuring that vocational education and training received by students was up-to-date and relevant to the world of work. Typically students completing Year 12 or Victorian Certificate in Education (VCE) studies would enrol in a 2-year full time advanced diploma course in international trade. It being a 3-stage course, students had a choice to study for a Certificate IV, which required only stage 1 completion, or a Diploma, which required stage 1 and 2 completion or an advanced diploma, which required stage 1, 2 and 3 completion. A typical one-year study consisted of studying 12 modules spread over two semesters. Modules studied during first year are shown in Table 5.1.

Table 5.1
List of modules for the first year of Diploma in Marketing (International Trade) course

	Module Name	**Nominal Hours**
1.	Accounting for non-accountants	51-68
2.	Economics for business	51-68
3.	Occupational Health and Safety	15
4.	International Economic Geography	51
5.	International Business	51
6.	The Marketing Concept	51-68
7.	Introduction to Business Maths	30
8.	Cross Cultural Familiarisation	10
9.	Business Organisation and Contract Law	40-60
10.	Import and Export Business Procedures	60
11.	Permits and Controls in International Trade	40
12.	International Trade Finance	40

In addition to core modules listed above students also completed a range of computing and writing modules during the year including Advanced Operations Word Processing, Advanced Operations Spreadsheets, Business and Presentation Graphics, Writing Skills for Work, Writing Workplace Documents, Negotiating Skills, Writing in Plain English, Computer Operations, Database Fundamentals, Spreadsheet Fundamentals, Word processing introduction, Electronic Mail and Introduction to the Internet. The computing applications modules aimed at ensuring that students developed appropriate skills to use information and communication technologies for the relevant industry. In terms of assessment, modules comprising this course are assessed using a competency-based model relying on criterion-referenced assessment.

As a common practice most VET courses are required to follow a competency-based assessment system (Maxwell, 1997). In this context learning outcomes and criteria for assessment are specified for a particular content and students' performance is assessed against these criteria. When students' performance is demonstrated to have met the established criteria, he or she is deemed to be competent in the required competency. This assessment regime works well for most workplace skills based assessment without the need of differentiating between relative performances of learners on any quantitative scale. However, in areas of content based learning, such as mathematics, some training providers have continued to use both competency based assessment as well as graded scores to differentiate between average and high achieving students (Maxwell, 1997).

The Introduction to Business Mathematics module was also required to follow a competency based training and assessment design. With the main objective of providing the learner with the knowledge and skills to apply mathematical techniques to a variety of business applications and decisions, the learning outcomes for the module consisted of six statements about students' performance:

- Perform with the aid of a calculator, or computer, percentage adjustments to common commercial situations including those requiring algebraic manipulation of formulae
- Explain the concepts of time value of money and be able to perform calculations involving simple interest
- Distinguish between simple and compound interest and perform calculations involving compound interest
- Define an annuity, list examples of a simple annuity and apply the annuity formulae to solve practical problems
- Calculate depreciation rates using the straight-line, reducing balance (diminishing-value), and units-of-production methods
- Plot and interpret straight-line graphs, apply them to business decision-making and discuss the significant features of non-linear graphs.

A closer examination of assessment criteria listed under each learning outcome reveals a clear picture of the mathematical knowledge and skills being desired during this module. The practical and skill focussed orientation of learning is also clearly evident from statements such as, “calculate simple interest using the equation I = PRT” or “solve problems involving transposing of the compound interest formula to find the present value, the interest rate and the number of time periods”. It is easy to notice from these and similar statements listed that the main emphasis of the course is towards developing practical mathematical skills and manipulation of formulas to calculate the value of desired variables. An analysis of words used to describe required actions (Table 5.2) reveals that out of 30 assessment criteria listed under these learning outcomes only 3 required students to engage with evaluating and communicating mathematics (discuss, describe, examine). In terms of using technology for learning mathematics, the module in its first learning outcome suggested that students needed to “perform with the aid of a calculator, or computer, percentage adjustments to common commercial situation”. Other learning outcomes had no mention of technology use but it was implicit that calculators could be freely used to carry out these calculations.

Table 5.2
List of action words used to describe mathematics competence in the assessment criteria statements of the module

Word	Frequency	Word	Frequency
Discuss/Describe/Examine	3	Define	2
Calculate/Compute	8	Manipulate	1
Solve	4	Distinguish	2
Prepare	2	Estimate	1
Apply	2	Compare	1
Operate	1	List	1
Use	1	Plot	1

The module followed an assessment process comprising of two components. One component was made up of six ungraded assessments conducted during the semester and the other component was made up of a graded final test paper. In order to pass the module students needed to obtain an ungraded pass in all six assessments spread through the 15-week semester. The final test was used as a summative assessment and offered a graded result ranging from a pass to a high distinction. Students who missed any of the six assessments could still pass the module if they took the final test and passed. The typical features of the course are summarised in Table 5.3.

Table 5.3
Typical features of the course

30 modules studied over 2 years full time
Each module ranges between 30-50 hours in duration
A typical module has 5-6 learning outcomes and each learning outcome is specified by a set of performance assessment criteria
Students need to demonstrate competence in each learning outcome to successfully complete the subject
Assessment is ongoing and needs to cover performance elements detailed for each learning outcome
Performance in final examination or a major assignment may be used for final assessment grade
If a student can demonstrate competence for each learning outcome during ongoing assessment, he/she does not need to take the final examination to obtain an ungraded pass in the subject
A student who may not have demonstrated competence for a given learning outcome during ongoing assessments may still demonstrate competence in the final examination and pass the subject with a grade.

Fitzsimons (2003) points out that while competency-based training encourages the assessment process to demonstrate students' performance in a practical sense, in the case of mathematical techniques and skills, assessment under classroom situations often boils down to testing of "carefully rehearsed academic routines". She argues that it is very difficult to judge a student as 'competent' in mathematics and suggests that this type of assessment fails to provide any assurance that "the student will know how to or wish to choose and use the appropriate technique when the need arises" (p 211). As a person responsible for ensuring fairness, quality and authenticity of assessment for the module, Cathy was aware of the challenges in terms of requirements of competency based assessment and appropriateness of assessment design and process from the perspective of learning context. We discussed the issue of assessment in several meetings and decided to use the opportunities offered by the MCA Online learning environment to incorporate greater authenticity in assessment tasks. These assessment tasks are described in greater detail in Section 5.4 under topic headings later in this chapter.

5.2.2 The Students

Two important factors influenced our decision to choose students undertaking the Introduction to Business Mathematics module for our blended learning experiment during this cycle of the study. Firstly, it was the subject coordinator and the teacher for this module, Cathy, who had been part of the MCA Online advisory group during the first cycle of the study and was keen to adopt new technologies in her teaching methods. Secondly, it was the nature and availability of student groups undertaking this module. As a second semester subject for first year Diploma in Marketing (International Trade) two classes of this mathematics module were being run on the same campus and Cathy taught both classes. In addition, during the first semester these students had undertaken a number of introductory computing modules and were familiar with basic computing, email and Internet searching. Students were assigned to individual classes by an enrolment management system and we as teachers and researchers had no influence over allocation of students to particular classes. These students were expected to undertake another mathematics module called business statistics in their second year. The availability of two similar groups (classes) offered us an opportunity to employ a quasi-experimental design and designate one class as a treatment group and the other class as a control group. The treatment group had 24 and the control group had 19 enrolled students at the commencement of the module. Both groups were similar in composition but statistically student allocation to particular groups was not based on random sampling techniques.

The treatment group consisted of 14 male and 10 female students. These students represented an ethnic mix highlighted by their place of birth as shown in Table 5.4. Eleven of the 24 were born in Australia and the rest were born overseas.

In terms of Internet access from home 20 students from the treatment group indicated that they had access to the Internet from their home. For most students it was their first enrolment in a post secondary course and 18 of the enrolled students were less than 20 years old. Six students were more than 20 years old including one who was more than 30. Most of these students (22) were recent graduates from secondary schools and had completed their year 12 studies in the last two years.

Table 5.4
Treatment group students- distribution by place of birth

Number of Students	Australia	Vietnam	Hong Kong	Turkey	South Africa	Philippines	Yugoslavia	Ethiopia	Poland	UAE	Thailand	Iran
Start	11	2	2	1	1	1	1	1	1	1	1	1
Finish	6	1	1	-	1	-	1	1	-	-	-	-

The control group consisted of 19 enrolled students including 11 male and 8 female students. The control group was smaller in size compared to the treatment group but both Cathy and I did not have any control over the selection of students for either group. Decisions about the allocation of students to particular classes was controlled by enrolment management and course selection officers and depended largely on total number of students seeking to complete the required number of studies for a particular course during the semester. The control group also demonstrated a distribution of diverse ethnic mix as shown in Table 5.5

Table 5.5
Control group students- distribution by place of birth

Number of Students	Australia	Vietnam	Hong Kong	India	Macau	Chile	Yugoslavia	Pakistan	Peru
Start	5	6	1	2	1	1	1	1	1
Finish	1	3	-	2	1	1	-	1	-

Most of the students in the control group were also recent graduates from secondary schools and had completed their Year 12 studies in the past two years. A total of 15 out of 19 were less than 20 years in age with only four aged between 20 and 30. In the control group, although more students were born overseas compared with the treatment group, a large number of them (15 out of 19) were locally educated and had completed their VCE qualification from Victorian schools. Amongst this group of students 13 students stated that they had Internet access from home. In terms of their diversity, age and educational background both groups appeared to be very similar except for the fact that in the treatment group Australian born students formed the majority grouping and in the control group Vietnamese born students formed the majority grouping.

As far as our design experiment was concerned we were particularly interested in the characteristics of the students in the group selected to be the treatment group and were keen to engage them in a blended online learning environment in mathematics. From an educational perspective, the treatment group with a diverse ethnic mix and a majority Australian born students reflected the larger population of VET courses more closely than the control group. With a greater proportion of treatment group students having access to the Internet from home and having completed their pre-requisite qualifications in the last two years, this group appeared to be more prepared for using an online learning environment in mathematics.

5.2.3 The Teacher

Successful integration of technology in classroom teaching practice requires a significant contribution and commitment from the teacher. Research has shown that a teacher's skills, attitude and motivation plays a crucial role in the success of technology based intervention in classroom learning (Brennan, 2003; Cashion & Palmieri, 2002; Norton & Cooper, 2001). As an experienced mathematics teacher Cathy had been teaching mathematics modules in the department for a number of years and had developed a bank of resources to teach relevant topics. She was also active in developing her own computer skills by participating in a number of professional development programs conducted by the institution. During my association with her for the development of the MCA Online website, where she acted as an advisory committee member, I found her to be a cautious but willing participant in implementing new technologies in classroom practice. She demonstrated a keen interest in learning new skills and maintained an open and sceptical position about the effectiveness of particular technological interventions in achieving learning and curriculum goals.

Cathy was also quick to notice the potential of web-based learning in attracting and retaining interest and attention of her first year diploma class students who were mostly young and enthusiastic about technology. In recognition of Cathy's interest in emerging technologies her department had nominated her to participate in a State funded professional development project. This project provided her a new laptop and opportunities for professional development. So, when the prospect of using a blended learning environment with her mathematics classes emerged, she was quite willing and enthusiastic about implementing it with her group of students.

5.3 Conjectures and Design

The MCA Online website developed during the first cycle of this study served as a base for the design of the module website on WebCT in the second cycle. The experience of trialling the MCA induction module in a number of settings during the first cycle provided us valuable insights into the design, usability and effectiveness of our online learning environment in supporting mathematics learning in mainstream vocational courses. The experience led us to draw tentative theories from our initial conjectures and helped in drawing new conjectures for the second cycle of the study.

Conjecture 2.1: Students' learning in mathematics can be supported more effectively if we presented the vocational course content in a blended learning format

An important assumption made during the design of MCA Online website was that if we provided easily accessible discipline specific online resources in mathematics from our website students from mainstream TAFE courses would be able to make use of these resources with some guidance from their teachers and exchange of messages on the discussion board. However, during trials it turned out that merely making useful resources available from a website was not enough to gain students' sustained attention and the use of these resources in their learning. The MCA Online website provided mainly general mathematics content via its learning units and any discipline specific content was limited to course guides and archives of past examination papers and solutions. We realised that it was essential to establish a link between vocational course content and the online learning environment before expecting students to invest their time in learning online.

Consequently, one of the main conjectures for the design and enactment of the second cycle of study focussed on the blended learning environment. We stipulated that student learning in mathematics can be supported more effectively if we presented the vocational course content in a blended learning format where face-to-face classroom teaching was supported by resources and activities located in an online learning environment. The blended learning format offered more opportunities to the subject teacher to integrate online resources and activities in learning and assessment tasks. It offered students an extension of their classroom in an online platform where it was accessible to them round the clock and contained additional resources for practise and brushing up work. A focus on this conjecture during the second cycle of this study also allowed the research to respond to the research question on factors affecting students' participation in a blended learning environment.

Conjecture 2.2: Presenting the course materials and learning tasks in a flexible way would allow students to access learning even outside face-to-face class times and this would lead to improved learning and retention of students

Our conjecture related to students' access and participation in the module was that when course materials and learning tasks are accessible in a more flexible way students' would be able to access learning even outside face-to-face class times and this would lead to improved learning and retention of students because those students who are unable to attend particular face-to-face sessions would be able to continue with the module and participate in learning activities. This conjecture was concerned directly with students' access and use issues and assisted this study to answer the research question on student's access and use of the blended learning environment.

Conjecture 2.3: The use of online communication tool in an asynchronous mode would lead to increased peer-to-peer and teacher-to-student support

Another important conjecture leading from the first cycle of this study was that the use of online communication tools in an asynchronous mode would lead to increased peer-to-peer and teacher to student support. It was anticipated that continual and extended use of discussion board communication would lead to the development of online peers who are able to solve problems using this new medium of communication to share knowledge and information. This conjecture also provided the necessary grounds to explore research questions on the access and use by students and the effect of the use of blended learning environment on the teacher's role.

Conjecture 2.4: Use of online tools and authentic data would be able to affect students' attitude towards mathematics positively and their engagement with class activities and mathematics would be enhanced

Another conjecture during this cycle of the study related to the use of online resources from the real world in authentic learning activities with the students. Mathematics taught using traditional methods and resources has been criticised for being disconnected with the real world experiences and pen and paper based calculations are unable to make connections to authentic activities taking place in the real world outside classrooms (Ainley, Pratt, & Hansen, 2006). Cathy had been teaching using these traditional resources and had been keen to make her learning tasks more authentic. She had used examples from newspaper cuttings to make her mathematics problems reflect real life experiences. With the help of web access available from the classroom Cathy seemed keen to explore the possibilities of using "live" data from authentic sources in solving mathematics problems with her blended learning group. Research has shown that the mathematics used in workplaces is highly context dependent and increasingly workplace mathematical practices are relying on the use of technology (Noss, Hoyles, Bakker, & Kent, 2005; Zevenbergen & Zevenbergen, 2004). As mathematics teachers we wanted students to become familiar with workplace contexts and the use of technology in solving mathematics problems. Our conjecture in this regard stipulated that the use of online tools and authentic data from the Internet would affect students' attitude towards mathematics positively and their engagement with class activities and mathematics would be enhanced. In this way this conjecture tied neatly with my research questions related to factors affecting students' participation in a blended learning environment and how it affects students' attitude towards mathematics.

Conjecture 2.5: Use of an online learning environment in a blended learning format would lead to a clear improvement in students' attitude towards mathematics

Mathematics teachers are generally slow to adopt new technologies in their teaching practice (Kaput & Thompson, 1994; Vale, 2004) and seem to have as a lingering cynicism towards effectiveness of technology in learning (personal observation spanning over 25 years). This cycle of the study offered an opportunity to include a quasi-experimental design and prompted us to make conjectures about the effect of the online learning environment on students' attitude and performance in mathematics.

In relations to students' attitude towards mathematics our first conjecture was that at the start of the course both control and treatment group students would show very similar attitude towards mathematics and there is likely to be no significant difference between the two groups.

We expected that the use of an online learning environment in a blended learning format would make a positive effect on students' attitude towards mathematics and consequently our second conjecture in relation to attitude towards mathematics was that there will be a clear improvement in treatment groups' attitude towards mathematics in comparison with the control group.

Conjecture 2.6: Students using a blended online learning environment would improve their mathematics scores more than those students who learn using traditional face-to- face methods only

Achievement in mathematics was assessed at the start of the module using a general mathematics information sheet – achievement pre-test (Appendix 3). Both treatment and control groups were given the achievement pre-test in general mathematics during the first week of the course. The purpose of this test was to establish if the two groups differed significantly in their mathematics ability at the start of the blended learning program with the treatment group. Our first conjecture in relation to students' achievement in mathematics was that at the start of the course the mathematics achievement scores of both groups would be very similar and there will be no significant difference between the two groups when their pre-test achievement scores are compared.

The mathematics achievement of both groups was once again compared at the end of the semester using their final test scores (post-test). This test was different in content and difficulty from the pre-test and aimed at testing students' knowledge and skills on the subject matter learned during the course. Since students in the treatment group were using additional online learning resources and activities in a blended learning format we expected them to perform better. As a result our second conjecture in relation to students’ achievement in mathematics was that the treatment group students would have significantly higher post-test achievement scores when compared with the control group.

5.3.1 Design of a Blended Learning Environment

The approach adopted in blending face-to-face to learning with an online learning environment emerged from the cycle one work on designing and trialling the MCA Online website with a number of student groups. Review of our first cycle trials clearly indicated that merely designing a useful online resource for learning mathematics was not enough to engage students in a sustained way to support their learning. Most students needed to see an explicit relevance between their course work and the use of online learning environment. First year youthful learners despite their acknowledged weakness in mathematics were reluctant to take on any additional load of mathematics work that did not relate directly with their immediate course requirements. Recent literature on strategies to support student learning also tends to favour an embedded approach over developing generic learning support resources (Dixon et al., 2005). Using a blended learning environment to support learning resonates closely with the embedded approach where learning support is provided with close cooperation and collaboration with the subject teacher and often extends over the full length of a semester. Recent research also indicates that blended learning where instructor led training is mixed with e-learning methods is being favoured by teachers as a teaching and learning strategy (Booth et al., 2003; Brown, 2003; Fisher, 2003; Franklin & Peat, 2001).

In order to create a blended learning environment for the treatment group we faced two tasks – develop an online environment for the module and design appropriate learning activities that make use of the online environment to complement face-to-face teaching sessions. As our first task we focussed on developing a new online environment which used relevant learning objects already created for the MCA Online website. We wanted to use an online platform that allowed access to only registered users and kept track of users’ access to different areas of the online environment. A powerful online learning management platform, WebCT, was available to us through our institution and served our purpose for the design of a blended learning environment. WebCT offered an online space where learning content can be organised and access to students can be regulated via login procedures. It also allowed administrators of online courses access to logs of students' use of particular resources from the online course. The WebCT also provided tools for one-to-one and one-to-many asynchronous communication via a message board and email facilities. While WebCT provided a course management tool for the online environment it also imposed certain restrictions in terms of design and content layout. Researchers have noted the limitations of platforms like WebCT and Blackboard in allowing freedom to course designers (Oliver, 2004).

As I had previous experience of using WebCT and instructional design I offered to organise a course website on WebCT and obtained instructor access for Cathy and designer access for myself. These access levels in online course administration allowed us to follow students' data regarding access to course content and communication via email and message board. Cathy and I had several meetings and worked collaboratively in developing the WebCT home page for the module. These sessions proved useful for me in developing a better understanding of the course content and assessment requirements of the module and at the same time were helpful professional development sessions for Cathy in terms of gaining new skills in using WebCT and developing online resources.

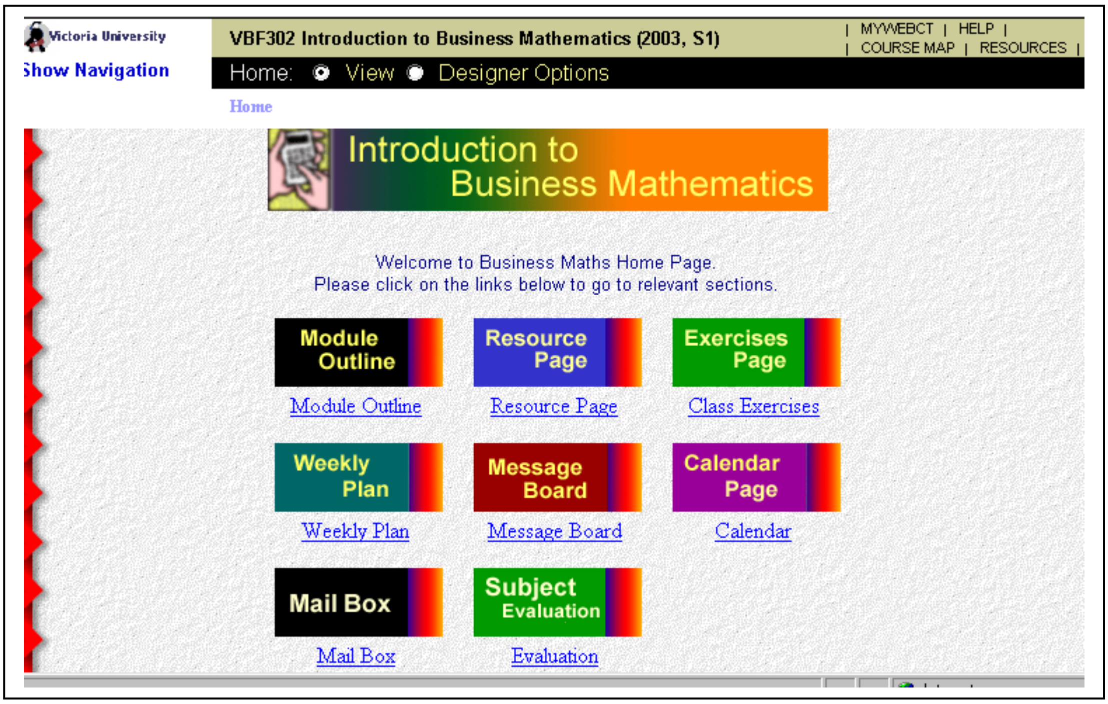

Figure 5.1. The WebCT home page for the business mathematics module

The module home page on WebCT was completed before the teaching sessions started and consisted of module outline, weekly plan, resource page, exercises page, message board, mail box, calendar and subject evaluation sections (Figure 5.1). The module outline contained a list of learning outcomes and how the module outcomes will be assessed. The weekly plan section provided a breakdown of weekly lessons and topic to be covered each week.

Figure 5.2. Class exercises section of module website.

The exercises page and the resource page links provided access to course content and supporting resources. The exercises page allowed the teacher to post weekly learning activities and related exercises before every scheduled lesson. This page served as a repository of all class handouts and learning activities collection. This section grew with time and all lessons from previous weeks remained available to students (Figure 5.2).

The resource page section contained topical listing of online resources supporting each topic for the module (Figure 5.3). Many of the resources listed in this section were borrowed from the MCA Online website and gave students a direct and easy access from their WebCT home page. Four types of resources including units, quiz, archive and tools carefully selected for each topic were listed as hypertext links from this page.

Figure 5.3. The resource page section of module website.

Links presented as Units provided direct access to MCA Online learning unit. For example on the topic of algebra students had direct links to learning units on *Working with like and unlike terms*, *Transposing equations* and *Directed numbers*. Students requiring brush up practice on basic algebra techniques could be directed to these units for self paced learning. These units offered static learning content as described in Section 4.2.3 of the previous chapter. Another type of resource presented to students was Quiz. The quiz link contained interactive learning activities appropriate for a selected topic. For example Algebra Transposition Quiz provided a java based interactive exercise from the A+ Maths website (Aplusmath.com, 1999) where learners could follow a step-by-step solution to randomly generated algebra equations. These interactive practice quizzes were selected to give students a chance to practice and review their skills and techniques. The interactive activities were self-correcting and provided both intrinsic and extrinsic automated feedback (Mihalca, 2005).

The third type of resource presented to students was the Archive links. These links provided access to a collection of frequently asked questions and answers by expert teachers on a particular topic of mathematics. The purpose of these links was to introduce the students to online communities of mathematics teachers and learners so that they could seek assistance from these sources when faced with problem solving situations related to mathematics.

The fourth type of link, Tools, were online calculators commonly used for calculating various business related calculations such as currency conversion, interest rate calculation, depreciation calculation etc. Many of these tools were originally located on the MCA Online website and were sourced directly from commercial websites such as banks and related financial websites. The use of these online calculators as a resource for this module was twofold. At one level these automated calculators allowed students to get answers to their problems and verify their answers obtained by pen and paper manual methods and at the other level they provided students with a taste of the tools and resources business and marketing professionals use on a day to day basis. The use of online calculators posed a tension and dilemma for Cathy and me because the course assessment and final tests were to use mostly pen and paper methods and use of online calculators were not expected to help students learn traditional methods of solving mathematics problems. However Cathy was supportive of the idea that online calculators are important tools being used in the industry increasingly and it was of value to our students to become familiar with them and learn to use them. The online calculators also offered opportunities for exploratory learning and problem solving because these tools could do the calculations quickly and show the results instantly (Bransford, Brown, & Cocking, 1999). She also agreed to include some learning activities in which online calculator use would be required and students would be encouraged to check their pen and paper calculation results with results obtained by online calculators.

Another important section of the module home page on WebCT was the Message Board section. This section allowed students access to a bulletin board where messages by students and teacher can be posted. This section of the home page also expanded with time as the module progressed. The message board allowed students to post messages and by default these messages were identified with the sender's name automatically appearing in the header of the mail. However, the sender had a choice to make their posting anonymous if they so wished by selecting the anonymous option in the message composition window. The 'track students' feature of WebCT in the administrator mode allowed me to view the summary of each user's mailing history in terms of original posts, articles read and follow up posts. This feature helped in tracking students' online access and message board use during the course.

In order to keep track of messages pertaining to particular mathematics topics the message board contained a folder for each topic and original postings and replies to messages pertaining to that topic were stored in that topic folder (Figure 5.4).

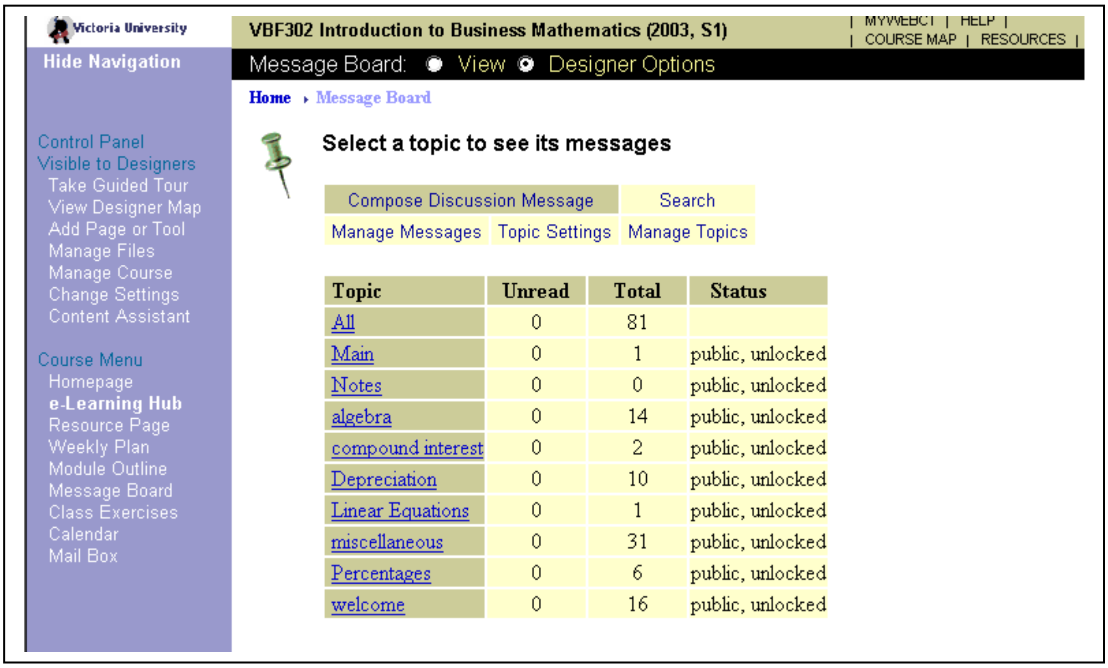

Figure 5.4. The message board section of the module website.

In addition to the message board students had access to a dedicated email section as well. This section allowed students to have private email with other students of the class and to contact the teacher by email. The WebCT email allowed the teacher and students to communicate with each other on an individual level.

A number of sections of the module home page including the Exercises Page and the Resource Page were continuously revised and updated during the course of the semester. New exercises and resources were added to these sections on a weekly basis and sometimes during the teaching session as per student needs. While designing the WebCT home page for the module Cathy and I became increasingly aware of the need for redesigning learning and assessment activities to make effective use of opportunities offered by the online resources (Oliver, 2004). But Cathy had to deal with a pedagogical dilemma. On the one had she had to remain faithful to the traditional classroom practice and the learning outcomes and assessment guidelines provided in the course outline and on the other hand she could see the advantages of modifying her teaching and assessment practice to allow students' experiences of using new technologies to enhance their learning. She was prepared to take calculated risks and agreed to include online activities as part of weekly assessment for the topics of Algebra and Depreciation. However, the final assessment test for both control and treatment group students had to be the same paper based test.

The design of the WebCT home page for the module served as an anchor for blended learning with the treatment group. In the blended learning sessions with the treatment group face-to-face teacher led sessions were complemented with online activities via the module home page.

5.4 Enactment Stage 2

This section provides an account of how the newly designed WebCT home page was blended with face-to-face teaching for the treatment group class. It draws on class observation notes, personal reflection and WebCT data to present a picture of teaching sessions conducted with the treatment group and identify factors and issues affecting participation and learning of mathematics in this class. I also observed the control group sessions and have drawn comparisons where necessary to highlight differences resulting from the use of online learning environment with the treatment group.

With the help of the timetabling officer Cathy arranged for her mathematics class to be scheduled in a multipurpose room. This multipurpose room had a rectangular shape and networked Pentium computers were available on benches along three sides of the room (Figure 5.5). The room had tables and chairs arranged in the centre to allow for teacher led classroom sessions. In the front of the room a large whiteboard hung on the wall alongside a projection screen for overhead transparencies. Cathy and I shared a large teacher's desk at the front of the room. A door at the end of the back row served for passage to this room allowing late students to quietly join the class while the teacher continued with her teaching. There were 18 computers along the wall and swivel chairs allowed students to float between central tables and computers on the side bench.

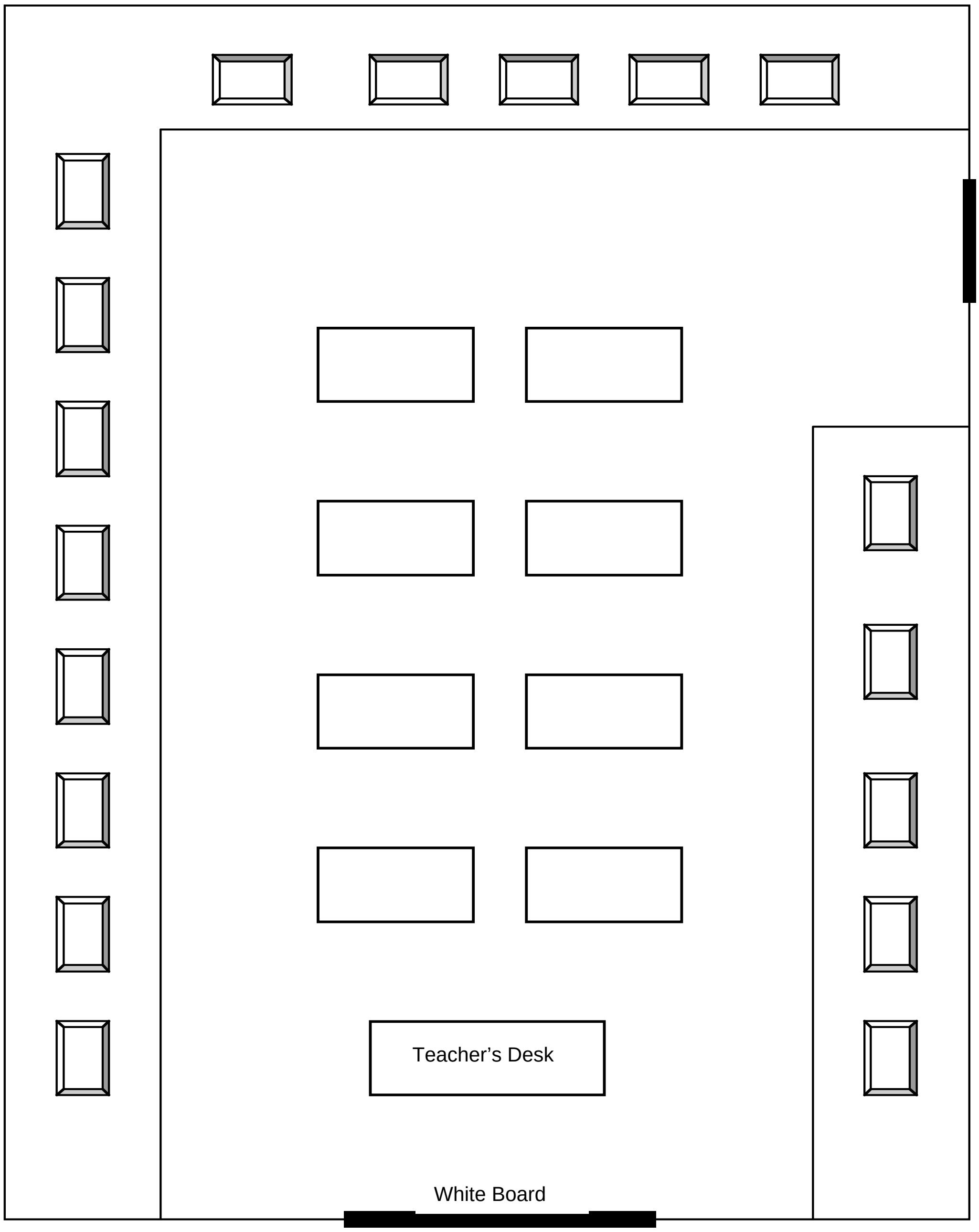

Figure 5.5. A sketch of the multipurpose room where mathematics classes with the treatment and control groups were held.

These networked computers had fast cable connection to the Internet and students had a choice to use either the Netscape or the Internet Explorer browser. The computers also had Microsoft Office applications such as Word, Excel and PowerPoint installed on all computers. We had set the default home page for the Internet as the university's WebCT home page to enable students to log in to their module home page easily. The login procedure required students to type first four letters of their last name followed by last four digits of their student ID as their user ID and their student number as their password for WebCT. After setting up the module on WebCT, I provided a list of treatment group students to WebCT administration for setting up student accounts for this module. Once the WebCT module was in place and students' accounts were created we were ready to start the blended learning experiment.

According to time tabling arrangements the control group class was scheduled for a 2-hour session in the morning from 9:00 to 11:00, and the treatment group class started from 11:10 to 1:10. The ten-minute gap between two classes allowed for a switch over time and a short break for teacher. Cathy would come prepared for both classes in the morning and stay in the room until lunch. I was present with Cathy during both control and treatment group classes, however, during the final four weeks I did not feel the need to observe the control group class as most of the routine in the control group class was repetitious and did not appear to be relevant to the needs of this study.

5.4.1 Session 1: Introduction to WebCT

The first session was devoted to introductions, housekeeping tasks related to the module and an introduction to the WebCT component of the module. During this session Cathy gave a general overview of the subject and the assessment requirements and explained to the class my role as a participant teacher and researcher. She informed the class that I would be present during the class for making observations and assisting in learning activities. Students were informed about their role and requirements as research participants and explained how confidentiality and ethical considerations would be adhered to during the research. They were also provided with a printed information sheet about the research (Appendix 11). Students from both the control and treatment group classes completed and signed a consent form for participating in this research (Appendix 12).

Cathy and I explained the blended learning approach being adopted for the treatment group class and asked students to clarify any concerns at this stage. All students appeared excited about the online component and only one student expressed some concern about his lack of computer skills. All students present during this session completed an Aiken Mathematics Attitude Test and took a pre-test on mathematics achievement. The pre-test on mathematics achievement was labelled as General Mathematics Information Sheet and comprised of ten questions taken from a secondary school mathematics course (Appendix 3).

The purpose of the pre-tests on attitude and achievement was to determine if the control and treatment groups differed significantly at the start of the module. After initial housekeeping and pre-tests on attitude and achievement we decided to introduce the module home page to the class. We wanted to make sure that students were able to use the online environment and had developed some familiarity with it before actual lessons had started. It was also necessary to find out if there were any hiccups or issues in terms of students' access to the WebCT home page. We asked the class to move to computers and log in to their module home page. It was their first experience with using the WebCT system. We had prepared a step-by-step instruction sheet for logging on to module home page on WebCT as the first task for students. This task was followed by second task that required students to post a message on the Message Board.

Message No. 5　　　　*Posted by Jacob*
Hey guys,

My name is Jacob and despite not doing math for about 7 years now, I'm excited to attack this module. I lived in Japan for a couple of years and am doing the course with the view to working with a company who deals with Japan. I don't have particular interest in football therefore follow no team, sorry.

Email is xxxxx@hotmail.com

Message No. 6　　　　*Posted by Donna*
Hi my name is Donna and I hate maths. ☺

xxxxx@students.xx.xx

Message No. 10　　　　*Posted by Sagar*
Hi my name is Sagar and the maths subject is my favourite and am so happy for doing this module, and I am so interested on this course for the future. Peace yo !!!

Figure 5.6. Sample students' messages on the discussion board.

Students were given printed copies of instructions to complete these tasks. We were available to circulate and assist students who needed help. Students worked in pairs and helped each other in logging onto WebCT and posting messages. There was an excitement about reading what others had written about themselves. This activity served as an icebreaker for the class and students began chatting to each other and appeared excited about using the online environment for posting messages. A sample of these messages is shown in Figure 5.6

Initial formalities and WebCT activities consumed most of the first session for the treatment group and towards the end Cathy indicated that our first topic on mathematics would be algebra equations. She also handed out a printed exercise sheet to students and asked them to attempt it at home and bring it to class the following week.

5.4.2 Topic 1: Algebra

Algebraic transposition of equations to find an unknown quantity has been considered necessary for solving problems relating to various financial calculations in the marketing and business industry. Two full sessions and one half session were devoted to learning about algebraic equations and how to solve them. At the start of the session Cathy wrote a number of simple algebra equations with one unknown quantity and solved these on the white board to demonstrate the procedure of "doing the same thing on both sides" of an equation. She invited students to guess the next step and a number of students responded to her prompts by suggesting correct answers. Some of the questions solved on the white-board included questions like:

$x + 6 = 14$

$3x + 10 = 40$

$x/2 - 5 = 15$

After spending some time on modelling and coaching the step-by-step method of solving simple equations Cathy presented word problems for simple equations to the class. An overhead transparency was placed on the projector so that the class could see the problems. Students were asked to assist in developing algebraic equations for these worded problems and then explain the steps involved in solving the equation. Observation notes from this session show that many students worked out solutions of these problems in their heads but were having difficulties in transforming word problems into algebraic equations. Typical word problems solved in this session included questions like:

- I earn twice as much as my sister. If our combined income is $90,000 how much does my sister earn? How much do I earn?

- A banana is 5 cents more expensive than an apple. Six bananas and four apples cost a total of $4.00. How much does a banana cost? How much does an apple cost?

After solving a number of word problems on the white board Cathy handed out an exercise sheet and asked students to solve the questions in their notebooks. Both Cathy and I circulated and assisted students in solving the questions. Students' individual work in solving questions from the exercise sheet revealed to us that nearly half the class had problems with transposition of equations and some had difficulty with working out order of operations correctly.

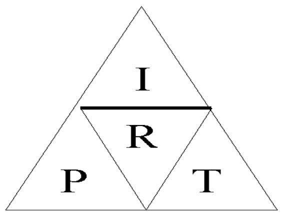

Figure 5.7. I = PRT triangle.

Later during the session Cathy explained how to use a triangle to help transposition for the unknown in I = PRT equation. As shown in Figure 5.7, Cathy drew a thick line underneath the term I and explained that if you wanted to figure out the expression for calculating T, then I will be divided by P and R. Using the diagram, she was able to provide a visual mnemonic to students to be able to transpose the given expression for calculating the value of different variables.

In the second half of this session we asked students to move to computers and attempt online activities on the topic of algebra. Cathy and I had planned two online activities to enhance students learning in algebra. In one activity interactive practice on solving simple equations was offered to students to reinforce the method learned in the face-to-face session. Students were given printed information on how to access this activity from their module home page on WebCT (Figure 5.8).

> *Online Algebra Task 1*
>
> 1. Log on to your course home page at http://webct.ceds.vu.edu.au using your user ID and password.
> 2. Go to the Resource Page and click on the link Algebra Transposition Quiz
> 3. Select Multiplication and Addition by placing a tick for that choice and click start button at the bottom of the flashcard page.
> 4. Solve the problems and try at least 10 questions online.
> 5. Check your score. Is it 100%? Well done.

Figure 5.8. Online algebra task 1.

The activity presented students randomly generated simple equations with one unknown quantity and required students to input the answer in the response box. Students' response was corrected automatically. Incorrect answers generated a response that displayed the correct working and solution for the problem. In this way a student was able to see steps required to solve the problem. The activity interface also displayed correctly answered questions as a fraction of total number of questions attempted. This self-correcting online activity was well received by students and they used pen and paper to solve the question before entering their response on the screen. Students also helped each other in navigating on the activity website and some students worked in pairs to solve the problems.

> *Online Algebra Task 2*
>
> In this task you have to write a worded problem similar to the ones given to you on your exercise sheet. This could be an age problem or a shopping problem or something similar. Use your own numbers to try the problem yourself.
>
> Post your algebra worded problem on the Message Board in the algebra topic folder.
> Cheers for now.

Figure 5.9. Online algebra task 2.

The second activity (Figure 5.9) was a creative task in which students had to think and generate a word problem from their everyday experience. There were two reasons for including this activity in the lesson. On the one hand it was designed with the view that writing word problems can serve as a powerful tool for learning algorithms (Fennell & Ammon, 1985; Golembo, 2000). On the other hand it served as a context for using the discussion board where students could see each other's work and attempt solving problems posed by other students.

Students attempted the first online activity during the class but ran out of time to attempt the task of writing a word problem and posting it on the message board. We reminded the class to attempt this problem from their home before next week's session. An analysis of students' posting and the use of discussion board by students is presented in Chapter 6, Section 6.3.2.

The second session on the topic of algebra started with Cathy reviewing some of the work done in previous week's session and introducing the concept of a normal pay rate and weekend loading. Because many students were working in part time and casual jobs they were already familiar with the notion of holiday loading. Cathy used their familiarity to launch into developing an algebraic formula to calculate pay involving holiday loading. Cathy modelled the solution for one problem on the white board showing the procedure of using x as a variable to express the relationship in an algebraic equation form. She used prompts to seek responses from students in building up the solution in a step-by-step format. Her interaction with students involved both triadic dialogue and funnelling techniques and led students' thinking towards a preferred solution path (Herbel-Eisenmann & Breyfogle, 2005). The students took notes in their notebooks and later referred to their notes while attempting to solve new problems. Later, Cathy introduced some problems where two algebraic expressions were required to solve the problem. She modelled the elimination method of solving simultaneous equations on the white board using examples from the exercise sheet. Following the modelling of solutions on the whiteboard students were given an algebra exercise sheet containing five word problems and asked to devise appropriate algebraic equations to solve these problems. Classroom observation of students' work suggested that most students needed assistance with the task of writing an equation based on a worded real life context such as the problem given below:

- A job pays $\$x$ per hour (normal rate). On Saturdays it pays time-and-a-half of the normal rate.

a) How much would you earn during a week when you worked 3 hours on Saturday and 20 hours at the normal rate? Express your answer in terms of *x*.

b) If the normal rate of pay was $12 per hour how much did you earn?

Cathy decided to spend some more time on working with worded problems and used questions from the previous exercise to help students see how to express a relationship described in a worded context as an algebra equation with the use of *x* as a variable. Observations of the class also revealed that academically more able students of the class were able to work out the answers for simpler worded problems in their head and appeared reluctant to use an algebraic equation to solve something that could be worked out mentally.

Later in the session students were asked to complete the online task of writing a worded algebra problem based on their everyday experience. This task was given to students in the previous week but, contrary to our expectation, students did not post any questions on the discussion board. However, during this session when we reminded students about the task, they promptly obliged and a flurry of activity took place where students helped each other in constructing and posting a message with their questions.

Classroom observation of students' written work also revealed that many students had forgotten their order of operations number skills and needed to re-learn and practice this skill. I discussed this with Cathy and we came up with the idea of using an online task in which students could practice skills required in solving order of operations problems. This quiz was similar to the transposition quiz and students could work at their own pace while receiving automated feedback on their attempts.

This session concluded with students returning to their seats and working on word problems from their exercise sheet. Some students stayed back at the computers to continue to work on interactive algebra exercises. Cathy and I went around the class to students working on worded algebra problems and helped them with understanding the steps involved in solving these problems. Before finishing the class Cathy informed the group that there would be an assessment test on the topic of algebra in the following week.

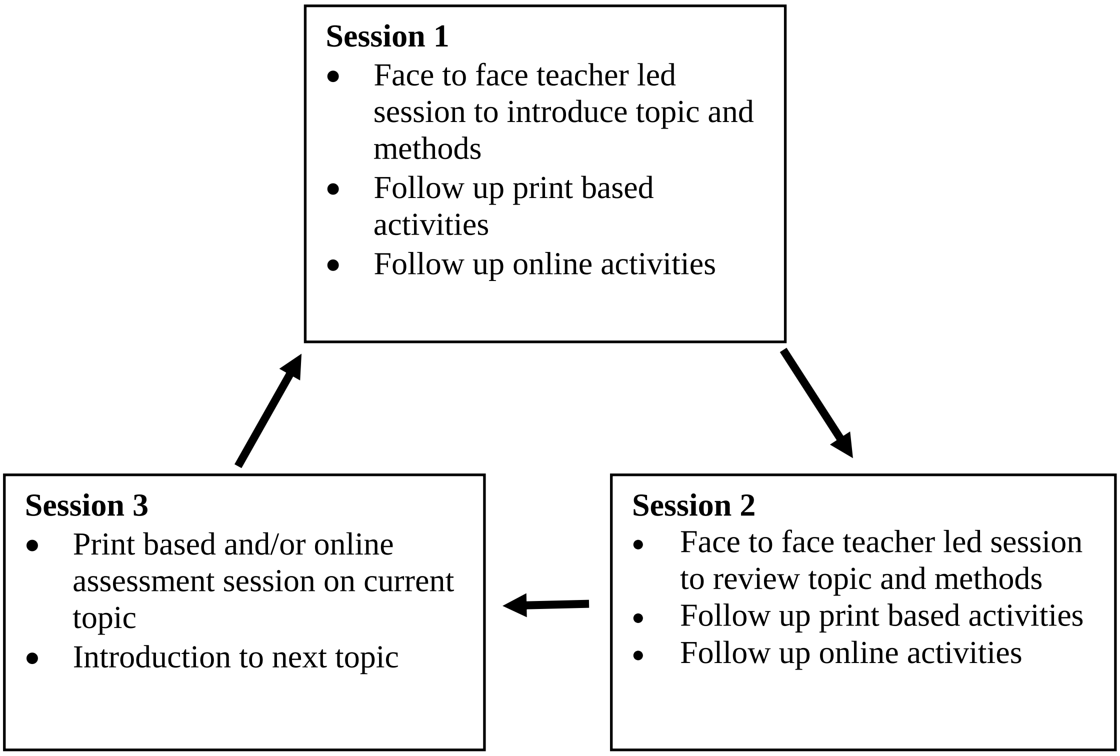

Figure 5.10. An outline of three sessions devoted to covering each topic area.

The algebra assessment activity consisted of two tasks and was completed during the first half of the third session on algebra. It consisted of an online task followed by a paper-based task on solving word problems in algebra. The online activity asked students to complete an interactive quiz on transposing equations where they had to complete at least ten questions within ten minutes. The online quiz was auto corrected and the final score of the quiz was displayed as a percentage score. This auto corrected score at the end of ten minutes was noted as student's mark for the quiz. Following the interactive quiz students were asked to complete a paper and pencil assessment task on worded algebra problems. Students were asked to solve five problems in half an hour. Two sets of printed assessment sheets were used containing similar questions so that students sitting next to each other may not copy each other's work during the assessment session. A final score for the assessment task was obtained by combining the scores from the quiz and the paper based task. The remaining time after the assessment task was used by Cathy to introduce the next topic: percentages. The three sessions described above and illustrated in Figure 5.10 reflect a pattern of teaching that was repeated for topics such a percentages, interest, depreciation and linear graphs in the following weeks.

5.4.2.1 Reflections and Interpretations

My reflections and interpretations from these sessions are based on personal observations in the classroom, records of online participation available from WebCT designer access, students' journal entries and interview sessions with selected students.

Observations from sessions covering the first topic of the module provide a glimpse of technological and pedagogical issues affecting the use of online learning in mathematics in a blended learning format and how we responded to these challenges in order to create an effective learning environment. On the technological front the first few sessions with the online group showed that most students were familiar with using computers and Internet but mature age students in the class had less experience of working with computers. The first problem faced by students was with logging on to course home page. The main problem was caused by the fact that after the first login the system opened a new window on the computer screen and asked students to change their password for security purposes. This was an unexpected and unfamiliar process. Students were surprised that when they logged in for the first time with their initial passwords they were being asked to change that password. Perhaps, it was due to lack of online experience with security sensitive websites. However, it was a once only process and later login procedure by students did not require them to change their password again.

Another technological issue that came up during the first session with WebCT use was that at least four computer screens froze while attempting the login process. It caused frustration in students, as they were not able to find out why their computers were not working properly while others did. It was discovered that because of a policy of not to switch off computers at the end of the day, some computers experienced a memory allocation problem and behaved erratically. This problem was easily resolved by restarting the affected computer.

Additionally, at least three students during first session had problems with their login details. It was discovered during login process that the spellings of their names were misspelt on the WebCT system and as a result when they used the combination of their name and student ID as required by the system, they could not login. This problem was resolved in the following week by sending an email to WebCT administration for correcting the names on the system. Research has shown that the teacher's ability to resolve technical issues quickly is critical in the success of online supported learning and we took note of addressing students' access issues as a priority (Bonk, Kirkley, Hara, & Dennen, 2001). While some problems were resolved at the classroom level, problems related to incorrect user names and passwords had to be referred to the IT department for follow up.

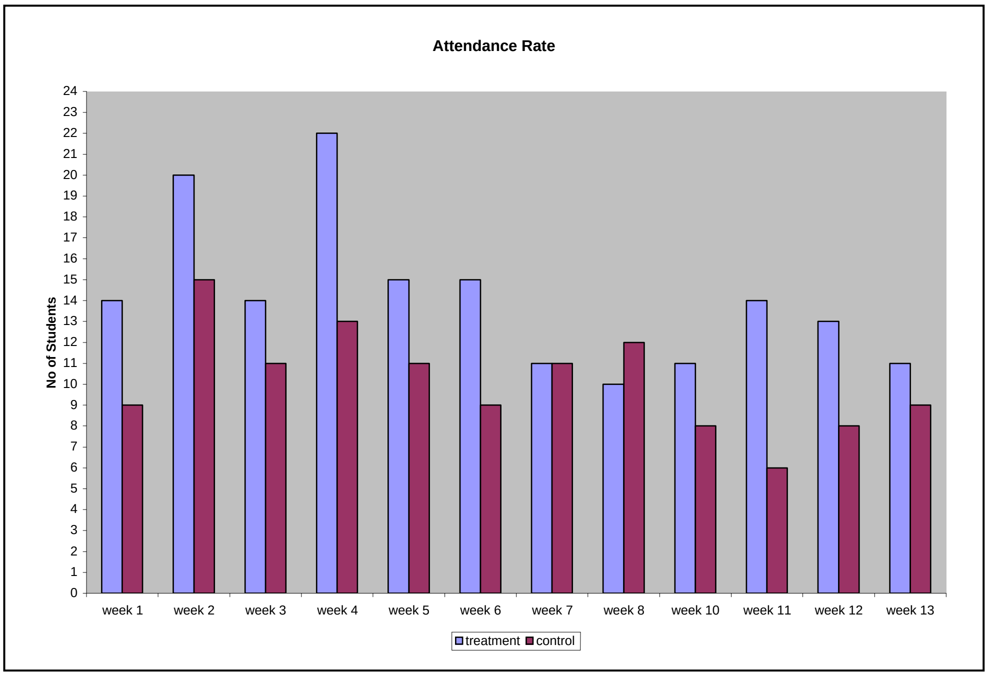

Figure 5.11. Classroom attendance pattern for the treatment and control groups.

At the class management level observations reveal that students' attendance pattern was a cause for concern. Although 24 students had registered to do this subject only 14 showed up for class during the first week. Attendance increased to 20 students in the second week but dropped back to 14 in the third. I observed that during these sessions, some students turned up late and missed the first part of the session. The problem of students' attendance was similar in the control group class where out of 19 students registered for the course only 9 showed up for the first session, followed by 15 and 11 in the second and third sessions. An overview of classroom attendance is shown graphically in Figure 5.11

Interestingly, out of 11 students interviewed from this course five indicated that either they were not sure or had changed their course preference from the previous year which tends to indicate that many students enrolling in this course did not have a clear direction about their educational goals. Attrition from vocational education courses is a well known problem in the field and in recent years our institute had been particularly concerned at the rate of attrition from its VET courses (Gabb, Milne, & Cao, 2006; Keith & Javed, 2004; Misko, 2000).

In terms of classroom management issues another interesting observation made during these sessions was that while most students showed an increased level of motivation in working with online activities, some students found easy diversions on the Internet and during one session at least five students while working on WebCT tasks were noticed to have opened other browser windows for reading personal emails or chatting with friends on the Internet. Considering that this demonstrated the confidence and multitasking skills of students, we ignored this distraction in the first instance but reiterated that while on computers students must focus on completing their online activity before being sidetracked.

Observation of students' work during the first session indicated that students were familiar with simple algebraic equations but most showed difficulties in working with equations where fractions were involved. Students were able to follow Cathy's modelling of the solution process by doing the same thing to both sides of an equation but there was little or no discussion on why these steps resulted in the correct solution. This was more clearly evident when students were presented with the word problem tasks and simple word problems were answered by students without the use of any algebra equations. Students were able to use mental maths to work out solutions for simpler algebra word problems. At this point students were exposed to more complex equations where mental solution was not easy and the need for using the algorithm was justified. Cathy's modelling of the solution process on the white board is indicative of a cognitive apprenticeship approach (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989). The theory of cognitive apprenticeship holds that masters of a skill often fail to recognise the importance of the implicit processes involved in carrying out complex skills when they are teaching novices. In her teaching Cathy carefully explained and illustrated tacit processes involved in solving algebra equations using a variety of examples and allowing students to observe, clarify and enact these processes through practice questions.

Student participation in online activities during the class session required a transition from face-to-face teacher directed instruction to computer-based learning. The idea of using the second half of a two-hour session for online activities meant that we were able to introduce the topic and have some paper based work done before moving to computers. We were also able to identify more able students from weaker students who required more attention. Not everyone was equally enthusiastic about using computers in a mathematics class and at least one female student did not like the idea of using computers to do mathematics. She was however happy to use her calculator. The idea of students working in pairs worked well because students were able to help each other out with technology issues and less enthusiastic students were able to play at least an observer role in watching how their partners worked with mathematics problems on the computer.

During the first online activity on algebra transposition, once students had become familiar with the screen layout and navigation, they seemed to enjoy the practice where feedback was instant and they could monitor their progress. Delors, In'am, & Roberto (1998) point out that using the new technologies is also a way of combating under achievement because people who experience difficulties under the traditional system are sometimes better motivated when they come to use them and are thus better able to show where their talents lie. I noticed that students' motivation had increased during the interactive online activity; perhaps it was because many students were able to experience success in solving equations using the technology. An entry from my class observation of these sessions reads:

> This task proved a success in online learning as most students seemed to enjoy their participation and success in learning the task. Many students used pen and paper to help them solve the questions and self-scoring as a positive experience for most. One student later reported that she liked this site and task very much

> and at home she helped her sister to practice algebra equations using this page. It appears that self-assessment part of online maths learning is welcomed by most students.
> [Observation notes: Thursday 16 August 01]

The second online activity on algebra required students to post word problems on the discussion board. This activity generated more interest than the interactive quiz because it allowed students to express their creative side. Both Cathy and I were concerned that students were having particular difficulties in transforming worded problems into algebraic expressions. By giving them an opportunity to compose worded problems we hoped to give students the experience of seeing the connection between the language of a worded problem and the mathematics expression for it in the form of an algebraic equation. This strategy has been used in the school sector and reported to have shown that students who practise writing worded problems on algorithms appear to have a greater sense and understanding of the meaning behind an algorithm (Fennell & Ammon, 1985; Golembo, 2000).

Students' participation in composing worded problems and posting them on the online discussion board was very encouraging. All 14 students present during the session posted questions and 44 postings from students were recorded. Many students attempted to correct each other's postings and also posted attempted solutions for questions composed by other students. Out of the 44 messages, 20 were generated by three male students who were among high achieving students from the class. In contrast with the interactive quiz activity where students with low confidence in mathematics also took an active part, the activity of posting questions on the discussion board and solving questions posted by others generated less interest by lower achieving students. Most messages were posted by students who appeared to be confident about their computer and mathematical ability. Other students contributed only in a token form by responding to the task set by teacher.

Cathy's use of collaborative and creative learning tasks and mixing them with teacher led instruction shows a pragmatic approach to teaching mathematics where both social constructivist and cognitive apprenticeship models could be applied to achieve desirable outcomes for students. While the first online activity on algebraic transposition could be conceived as using the technology as a servant where it was used as a supplementary tool to amplify cognitive processes, the second online activity of constructing and posting worded problems on the discussion board can be seen as using the technology as a partner in facilitating understanding (Goos, Galbraith, Renshaw, & Geiger, 2003).

5.4.2.2 Assessment

The assessment for the online group consisted of an online task where students were asked to use an interactive equation quiz to solve a minimum of ten problems. This task was followed by a paper-based task where students were required to solve two algebra questions including one worded problem. Three different versions of this paper-based assessment were used so that students sitting next to each other may not confer and copy each other's answers. One version of this paper is shown in Figure 5.12. Both treatment and control group students completed similar paper based tests but the treatment group was also given the online quiz as the first part of the test.

Algebra Test

Question 1 (1+3 marks)
Solve for x

(a) $x - 8 = 23$

(b) $\frac{3x + 5}{2} = 6$

Question 2 (6 marks)
Last week porterhouse steak was $4.00 more expensive (per kg) than lamb chops. If 2kg of porterhouse steak and 3kg of lamb chops cost $47.75

(a) What was the price of porterhouse (per kg)?

(b) What was the price of lamb chops (per kg)?

Figure 5.12. Paper based test questions on the topic of algebra.

Treatment group students appear to have done very well on the online quiz task. In the given period of ten minutes at least four students were able to do more than 30 questions whereas on average students completed 18 questions. The online quiz questions were auto-corrected by the computer but students were unable to change their incorrect responses and their quiz score reflected how many questions were answered incorrectly. Based on quiz results the treatment group received a mean score of 84% with a median score of 86%. Since the control group did not take part in the online quiz it is not possible to compare the results of the treatment group with control group on the measure of online quiz performance.

However, the same paper-based test was given to both groups and it is possible to compare their performance on the paper-based test. As shown in Table 5.6 mean and median scores of treatment group on the paper-based test is lower than mean and median scores of control group. This may appear to show that control group students on average performed better than treatment group students on paper based testing in algebra. Nonetheless, it is also worth noting that based on performance of both groups on question number one on the test, which was an algorithm based equation solving question, it will become clear that 64% students in treatment group had correct answers compared with 46% of the control group. It may be assumed that students practice with online algebra tasks had contributed to their performance in solving algebra transposition problems favourably compared with traditional methods used with the control group.

Table 5.6
Comparison of Algebra Test Scores

		Online Test		Paper Test			
	No of Students	Mean Score%	Median Score%	Mean Score%	Median Score%	Correct Question 1 %	Correct Question 2 %
Treatment Group	22	84.3	85.6	42.3	40	64	14
Control Group	13	NA	NA	50	60	46	31

The number of students participating in online quiz testing may also have affected assessment comparison because during this session two new students had arrived for the treatment group class for the first time. As can be seen from the students’ attendance pattern (Figure 5.11), during the fourth week the largest attendance was recorded. So, it appears that the presence of new students in the treatment group who had not taken part in class activities prior to the assessment may have impacted on the comparisons unfavourably for the treatment group. It is also evident from the attendance graph

(Figure 5.11) that fluctuations in attendance were more prominent in the treatment group class compared with the control group.

Results from the pen and paper test on algebra also indicate that treatment group students performed poorly on the worded algebra question (question 2) and it may suggest that the online activity of writing algebra questions with the treatment group may have impacted negatively on students’ performance. Only 14% students from the treatment group could answer this question correctly compared with 31% from the treatment group. There are two explanations possible for this. One is that, students in the treatment group were distracted by online activities and as a consequence could not get enough pen and paper practice for solving word problems on simultaneous equations. The second explanation could be that new students taking the algebra test did not learn the topic like other students who were in the class from the start. In fact only three students from the treatment group and four from the control group answered the word problem involving simultaneous equations correctly on the test.

5.4.3 Topic 2: Percentages

The topic of percentages aimed to cover the second learning outcome from the module and focussed on developing students’ proficiency in working with percentages. Calculations involving percentages are a key skill in business and marketing calculations. Two sessions were devoted to this topic and were designed to cover aspects such as calculations of commissions, discount, wages, profit and loss and the Goods and Services Tax (GST). The first session on percentages started immediately after the assessment test on algebra was completed during week four. The assessment task took about 30 minutes and the remaining 90 minutes were given to learning percentages.

Cathy started the topic with revision of concepts related to percentages. She introduced the topic with examples of percentages in everyday use such as calculations involving GST and sales promotions. She used the whiteboard to show equivalence of percentages with fractions and gave examples of how percentages can also be expressed as decimal numbers. The emphasis during this lesson was placed on learning applications of percentages in everyday business operations and a basic understanding of number skills associated with the use of fractions and decimals was assumed. Using a cognitive apprenticeship approach Cathy modelled solution processes of various percentage problems on the white board. Her exposition involved students' active participation in building a solution. She prompted students to think about how a problem can be solved and asked them to suggest the next step and funnelling their responses to lead their thinking to a desired path (Herbel-Eisenmann & Breyfogle, 2005). Students who were less willing to speak up were encouraged to respond by Cathy addressing them by name and seeking a response.

A casual observer could easily misjudge Cathy's teaching approach as classical direct instruction, a teaching method often criticised by researchers as not actively involving students and failing to challenge students to think at higher levels of synthesis, analysis and evaluation (Handal, 2003). One of the basic tenets of direct instruction expects teachers to use scripted lesson plans (Engelmann & Carnine, 1991). In her teaching Cathy led the teaching session with the authority of a teacher but her script was not pre-determined and her teaching approach allowed for exploration of ideas by students. She placed special attention on the associative stage of learning (Anderson, 1983) to ensure that students' misunderstandings of key concepts can be clarified and corrected. In fact during the session her teaching style was able to create a transition from teacher directed learning to cooperative and exploratory learning. Typical examples of problems involving percentage calculations modelled during the lesson included questions like:

- Jan works for a fixed amount of \$250 per week plus 1.75% of the sales price of all items sold. Find the total income for the week if the total sales price of all items sold was:

  (a) \$35,000 (b) \$125,000 (c) \$385,000 (d) \$53,250

- A product that is listed for \$59.98 is discounted down to \$56. What is the rate of discount given?

- A store wishes to get rid of its old stock of fridges that retail for \$1200, so it marks them down by 28%. You go to that store and you tell the salesman that you are prepared to buy a fridge provided you receive a further 10% discount if you pay cash. How much should you pay if the salesman agrees to the 10% cash discount?

The online activities for the topic of percentages were introduced during the second session. The first part of this session was spent doing paper-based questions involving percentage calculations and Cathy used the whiteboard to model solution processes. Students worked in pairs to discuss each question and interpreted the descriptive questions to work out what calculations are desired and what methods can be used for calculations. The first online activity on percentages aimed to introduce students to the archives of Ask Dr Math questions and answers on the Internet as shown in Figure 5.13.

Online Task 1

In financial circles there is a popular method of working out how long will it take your money to double at a given interest rate. It is known as the 'Rule of 70'. Find out more about this rule of 70 from your course Resource Page via the link 'Interest Problem Q and A' under the Percentage section.

Problem: Can you work out how long it will take to double $5000 at the interest rate of 9% p.a.

Figure 5.13. Online Task 1 on the topic on percentages.

Students were given a task of locating particular information related to percentage calculations and interest rate. The purpose of this task was to expose the vast array of information on common math problems available from the Internet. Our intention was to train the students to access Internet based knowledge sources in problem solving involving mathematics.

Online Task 2

To answer the following questions you will need to go to the Home Loan Calculator link from the Resource Page. The Commonwealth Home Loan calculator offers 3 types of loan calculations. Select appropriate calculations to carry out the following tasks. Once your calculations are done post your answers on the Message board.

1. You wish to borrow 100,000 dollars for an owner-occupier home loan at the basic variable rate from the commonwealth bank. Your loan term is 20 years and you wish to make fortnightly repayments. How much will be your repayments per fortnight?

2. In the above loan if you decide to pay $100 extra per fortnight how will this affect your loan repayment term and how much interest will you save?

3. You earn $40,000 p.a. and you are allowed to use one third of your wages in loan repayments. At the current basic variable rate from commonwealth bank how much money can you borrow if your term of loan is 20 years?

Figure 5.14. Online task 2 on the topic of percentages.

The second online activity on the topic of percentages included an exploration of an online home loan calculator (Figure 5.14). This activity was designed to encourage students to explore the relationship between the interest rate and the loan repayment amounts and principal over a period of time. Students were expected to manipulate different variables in an online calculator to model different scenarios and analyse the output in terms of financial decision-making.

The two online tasks on the topic of percentages aimed to extend students' understanding of percentage based calculations using a constructivist paradigm. Here the activities were attempting to incorporate technology in the role of a 're-organiser' of learning rather than 'amplifier' where technology would play a subservient role of simply creating efficiency in calculations (Goos, Galbraith, Renshaw, & Geiger, 2003). Unlike the algebra online tasks where the focus was on developing students' proficiency in manipulating simple equations during percentage online tasks the emphasis was on providing opportunities for deeper understanding through problem solving and exploration. The percentage online activities were not aimed at providing skills practice for error reduction and automation.

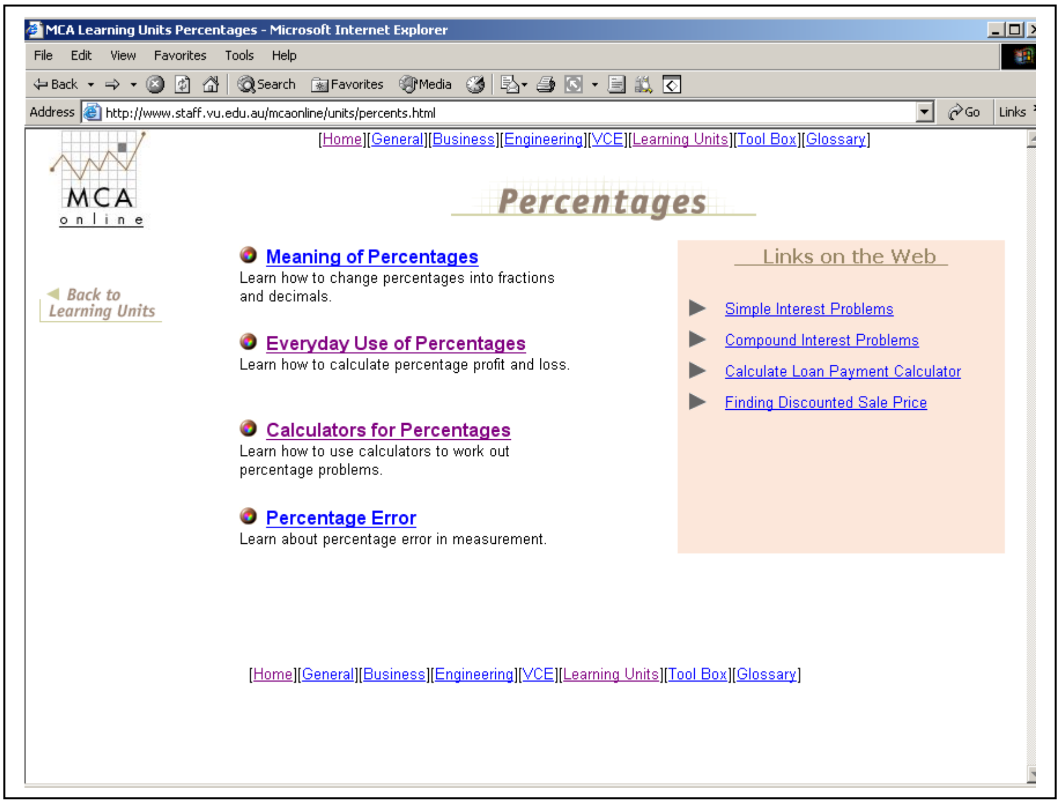

Figure 5.15. The MCA Online website unit on percentages.

During our use of online activities for percentages we were aware of the positive impact of technology use when it is used in exploring and problem solving (Tarr, Uekawa, Mittag, & Lennex, 2000). We paid special attention to give students an opportunity to explore the technology for non-routine learning such as finding out different ways for estimating percentages and interest calculations and exploring the relationship between loan amount, loan period, interest rate and the effect of extra payments on interest savings. At the end of this activity many students were astonished to see the effect of compound interest over a 25-year period as the interest paid exceeded the amount of original loan.

Cathy also asked students to visit the MCA Online unit on percentages (Figure 5.15), which they could easily find from their course resource page on WebCT. It helped students in revising their basic skills and knowledge on the topic of percentages. This unit from the MCA Online website was particularly useful for students who needed to learn and practice how to express percentages as decimals and fractions. The percentages unit consisted of topics related to meaning of percentages, everyday use of percentages, calculators for percentages and percentage error. Students were shown how they could use the activities available from the MCA Online unit in a self-paced way to help them learn about percentages. I observed that the mature age students from the class were particularly interested in exploring this site.

After the online activities were completed students were asked to reflect on their experience of working on these activities with particular focus on exploring the Ask Dr Math archive and experimenting with an online home loan calculator. Students were asked to post their answers and reflections on the discussion board and encouraged to comment on their experience of using these activities. Students who had completed their online tasks early returned back to their desks and continued to work on the percentage exercise sheet (Appendix 13). Cathy informed students that solutions to the exercise sheet on percentage calculations were posted on the course home page and students could use this answer sheet to self-correct their work.

5.4.3.1 Reflections and Interpretations

During the lessons on the topic of percentages both treatment and control group student attendance varied significantly. In the treatment group during first session on percentages 22 students were in attendance but in the following two sessions the numbers dropped to 15. The attendance pattern was similar in the control group where 13 students attended the first session but in subsequent sessions the numbers declined to 11 and 9 respectively. Although attendance fluctuated unpredictably a core group of regular students emerged in both groups and continued with the subject for the rest of the module. Initially, I was concerned that something to do with my research design might have caused this pattern in attendance but talking to Cathy and other teachers confirmed that the drop out in numbers was a normal occurrence and reflected on the nature of first year diploma students who were not sure if they had enrolled in the right course. Callan (2005) points out the three major reasons for VET students leaving a course without completing any subjects. These are perceived poor quality of the teaching staff, the content of the course not matching students' needs and the course not being able to fit into the demands of their job. Most of the students who dropped out from the class had attended less than 50% of the classes. Teaching style or poor performance in assessment does not seem to be the likely cause of dropouts because most of those who dropped out had successfully passed their first assessment task.

Technology issues for the treatment group were resolved for the most part and all students had become familiar with the process of accessing the module home page on WebCT. One student reported that he was unable to access the module home page from his home computer due to browser problems but managed to access it from a friend’s home. Another female student reported that she had found the site to be very useful and accessing it from her home allowed her to help her sister with learning maths. From students’ journal logs it was noted that three students were heavy users of the Internet and reported that they spent 15 to 20 hours per week on the Internet. The rest of the students reported usage between 1 to 10 hours. Researching for assignments on the Internet was the main usage reported by students. Other online activities reported in their journal by students were emailing, chatting, downloading, looking up news and playing games. Learning mathematics on the web was a new experience for students and they were unfamiliar with websites on topics of mathematics.

The online tasks during this topic were exploratory in nature and students' participation in these tasks was quite active and engaged. The tasks allowed students to work in pairs or small groups and this allowed students to help and guide each other in their use of the computer and Internet. Classroom observation of activities in both treatment and control groups during this topic revealed that there was more active peer learning happening in the treatment group class compared with the control group class where students worked mostly individually on printed worksheets.

> The online group appears chattier and socially interactive maybe due to the fact that students have to move about in the class to work on computers and in group tasks. Cathy has given a worksheet for practice to all students. She circulates in the class to help those who may need individual attention. She is unable to help all at the same time and some students have to wait for a long time before she can get to them. Unlike the control group students in this class seems more ready in helping out each other.
> [Observation notes: Thursday 23 August 2001]

While working with websites on mathematics topics students confronted two kinds of problems. Students were unfamiliar with the symbols used on the Internet to communicate mathematics and required explanations of the ASCII equivalents of common mathematical operations such as division, square, square root, indices notations etc. In addition, despite their good skills in using computers and the Internet, many students were unsure of how to work with interactive online systems such as financial calculators. Use of online financial calculators required some prior knowledge of variables such as loan amount, loan term, owner-occupier and investment interest rates etc. Once students were familiar with the terms their confidence grew in using the tool and it led to deeper exploration and discovery of patterns related to the home loan problem. They appeared more engaged with the task while working with authentic industry tools such as the online loan calculator. Students were quite surprised to find that banks charged so much interest to home lenders and how extra repayments can affect the loan term and interest paid. The online simulation of the mathematical model appeared to be a very powerful tool for learning.

In terms of out of class access and use of online learning on the module there was little, if any, independent activity by students. Only three messages were recorded on the topic of percentages in which students simply posted answers they had searched and located on the Internet. Students also did not make use of online resources from outside class and their Internet access to the module home page was mainly from campus-based computers. It appears that students were very selective about what online activities they would engage with. If the assessment for the topic did not require them to work with an online task, most ignored the activity when they were given a choice. As a result, in comparison with the Algebra online activities, the sessions on percentages generated less visible activity online. Although the nature of online activities for this topic was more closely aligned to the constructivist learning paradigm, students' practical orientation in relation to the assessment task meant that online exploration of the topic remained confined largely to classroom based access and use.

5.4.3.2 Assessment

The assessment for the topic of percentage was conducted during the first part of session three on the topic of percentages. The assessment comprised of four questions from an everyday business context and students had to carry out percentage calculations (Figure 5.16). Two sets of the tests were prepared comprising similar questions and students sitting next to each other were given different versions of the test (Appendix 20). Students were allowed to use calculators for these calculations.

The assessment did not include any online activity and students were not penalised for not participating in online activities or discussion board postings. Prior to the assessment on percentages students were told that the test on percentages will be a paper-based test and online activities did not constitute assessment for the topic. While the control group class was given two sessions of face-to-face learning with the help of pen and paper exercises and class discussion, the treatment group class had both face-to-face learning with the help of pen and paper exercises and online activities. Students had access to online resources to practice percentage skills and explore archive of questions and answers on the topic of percentages. For assessment purposes on this topic both control and treatment group classes were given the same paper based test on percentages.

Percentage Test

1. A computer has a list price of $5670, but it is sold for $4896. What is the rate of discount offered?
2. An item is sold for $188 (This price includes GST). How much is the GST paid on the item?
3. Last year Peter received an income of $44,000. His income is calculated on a retainer plus commission of 5% on all sales. If his sales for the year were $300,000 what was his retainer?
4. How much would you sell a product with a cost to you $168 and a 33% mark-up?

Figure 5.16. Paper based test questions on the topic of percentages.

Cathy and I were aware of the constraints imposed by competency-based curricula and for comparison purposes we kept the assessment for control and treatment group as similar as possible. As we progressed along the blended learning path we became increasingly aware of the fact that the use of technology was not playing a neutral role in assisting learning of content but it was shaping the content at the same time (Goos, Galbraith, Renshaw, & Geiger, 2003; Hoyles, Noss, & Kent, 2004).

Table 5.7
Comparison of percentage test scores

	No of Students	Mean Score	Median Score
Treatment Group	15	71.7	75
Control Group	9	51.4	62.5

Comparison of assessment test scores between treatment and control group classes (Table 5.7) shows that the treatment group performed slightly better than the control group. It was a little bit of a surprise to us because both Cathy and I were concerned that we had spent less time with the treatment group class with respect to paper based learning and that they may not perform as well in comparison with the control group. In addition to showing better scores on the assessment task the treatment group class appeared to be more friendly and social where students interacted with each other during their class work. The cohesiveness of the treatment group could be partly attributed to the blended learning format that allowed for greater interaction between students.

5.4.4 Topic 3: Interest

Although some problems based on interest rate calculations and GST calculations were covered during the percentages topic, simple and compound interest concepts were treated as a separate topic and covered during two sessions immediately after students had done work on the topic of percentages. Interest rate based calculations are considered to be an important part of business and marketing industry and our module clearly stipulated that students should be able to “distinguish between simple and compound interest and perform calculations involving compound interest”.

The first session on simple and compound interest topic started with a short review of percentage concepts and an explanation of how to represent percentage as a fraction and as a decimal number. Cathy’s approach to this topic was similar to previous topics and started with teacher directed activities and gradually blended into a cooperative and problem solving session. She used modelling and coaching strategies to facilitate cognitive and associative stages of learning (Anderson, 1983) and introduced online activities as an anchor for exploratory learning with problems involving real life contexts (Bransford, 1990). Typical problems in print based exercises given to students included questions like:

- Find the amount of interest earned on a principal of:
    $5000 at 3.5% per annum over 3 years
    $8,600 at 5%p.a. over 4 years and 3 months
    $15,000 at 6%p.a. over 2 years and 6 months
    $6,700 at 2.5%p.a. over 3 years and 9 months

- How much interest would you earn if you invest $3,500 for 3 years at 8% p.a. compounded quarterly?

These print based problems were designed to help students practice using the compound interest calculation formula derived earlier in the session on the whiteboard. Students were permitted to use calculators but were instructed to estimate their answers first. After the initial session focussing on declarative and functioning knowledge on calculations of simple and compound interest, Cathy moved the class to the online activities session where students were expected to use the course website to carry out tasks involving interest rates problem.

Cathy introduced the online compound interest calculator and asked the class to try solving questions from the printed exercise sheet using the online calculator (Figure 5.17). As some students had already solved these problems using pen and paper, they were keen to see if the online calculator would give them the same answer. A typical display of the solution provided by the online compound interest calculator showed a detailed working of compound interest calculation showing both the long table method that included step by step working out for each period as well as calculation using the compound interest formula as a short cut (Figure 5.17).

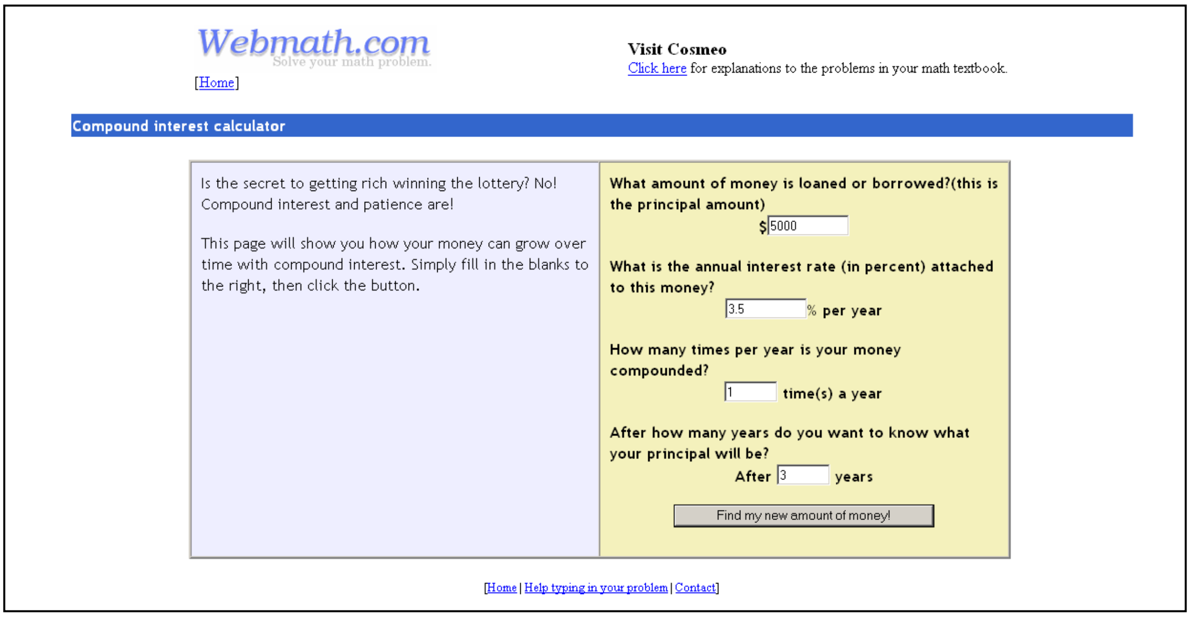

Figure 5.17. Compound interest calculation input screen 1.
Source: www.webmath.com.

Students used data from questions provided in the exercise sheet to test the online compound interest calculator. Once a problem was entered correctly, the online computing tool provided a detailed solution as shown in Figures 5.18 and 5.19.

You want to calculate your new prinicpal from:

- an initial investement of $5000
- at 3.5% annual interest,
- compounded 1 times per year,
- after 3 year(s).

Before we start, be sure to convert your interest rate at the time of compounding, 3.5%, into a decimal by dividing it by 100, so 3.5% becomes 0.035 for calculation purposes.

Year 1, compounding time #1

- Current principal is $5000.00
- Interest earned on $5000.00 is $5000.00 × 0.035 = 175.00
- This makes your new pricipal $5000.00 + $175.00 = $5175.00

Year 2, compounding time #1

- Current principal is $5175.00
- Interest earned on $5175.00 is $5175.00 × 0.035 = 181.12
- This makes your new pricipal $5175.00 + $181.12 = $5356.12

Year 3, compounding time #1

- Current principal is $5356.12
- Interest earned on $5356.12 is $5356.12 × 0.035 = 187.46
- This makes your new pricipal $5356.12 + $187.46 = $5543.59

In the end, $5000 has turned into $5543.59.

You have made $543.59

Figure 5.18. Compound interest calculation output screen 2 part 1. Source: www.webmath.com.

In the end, $5000 has turned into $5543.59.

You have made $543.59

While the above table is instructive, and will hopefully help you to understand how compound interest works, there's a shortcut to getting the final answer, that works like this...

Notice that at each compounding step above, the new principal can be found by applying this formula:

NewPrincipal = CurrentPrincipal × (1 + r)

where r is your interest rate at the time of compounding, in this case 3.5% (or 0.035 in the calculations).

As an example, look at the first compounding step:

$5175.00=$5000.00 × (1 + 0.035).

And the second:

$5356.13=$5175.00 × (1 + 0.035).

In fact, the whole compound interest amount boils down to multiplying (1+r), or (1+0.035), times your original principal 3 times (3 years at 1 compouding(s) per year).

Mathematically though, this is equivalent to multiplying your orginial principal by the factor $(1+0.035)^3$.

If we do this, we'll get that your final amount is:

$\$5000.00 \times (1+0.035)^3 = \$5543.59$

Which is the same result obtained in the step-by-step analysis. Wow!

Figure 5.19: Compound interest calculation output screen 2 part 2. Source: www.webmath.com.

The simulation of compound interest calculations using the powerful online tool provided by Webmath website helped students verify their own solutions as well as clarify their thinking regarding how the shortcut formula for compound interest calculation works. One student in the interview noted that:

> *… those special financial calculators and those special tasks that we can do, solidifies that information (how formula works) in your mind, you see how it works, you do a few more examples and you think 'even if I get stuck I can always come back here', and use these to check my answers.* [Interview transcript: Student – Juang]

Following an introduction to the online calculator for compound interest calculations Cathy extended the range of questions to include scenarios from real life situations and asked students to solve and comment upon possible solutions. Students had to select from a range on online calculators to choose the appropriate calculator for their problem. In this way students were able to work on compound interest problems from a range of contexts. First, Cathy modelled the solution of a typical compound interest problem on the white board and demonstrated how the shortcut formula can be derived from step by step calculations in a lengthy solution. Then students were asked to practice the formula on questions from the exercise sheet.

Online Task 1

Let us suppose you are 20 years old and wish to retire at the 65 as a millionaire. What amount of money would you have to deposit at a rate of 10 per cent in order for this one deposit to make you a millionaire?

Log on to your course home page
Click on the Resource Page from your Course Home Page
Locate and click on the Compound Interest Calculator link under the Percentages section.
Read instructions on how to use this calculator to work out the above problem.

Also, solve the following problems using the same calculator:

At what interest rate your money will double if you deposited $5000 for 6 years.
What will be the value of your money in 5 years if you deposited $10000 at the compound interest rate of 7% per annum?

Figure 5.20. Online task 1 on the topic of interest.

In one online task (Figure 5.20) students were asked to explore the compound interest calculations using an online tool that reproduced the modelling shown earlier by Cathy on the whiteboard. In another online task students were asked to work with real time data provided by the Internet and calculate the value of an investment calculation in a foreign currency (Figure 5.21).

Online Task 2

You are planning to invest $20000 in an investment in Thailand. The investment guarantees a return of 12% compounding annually.

Use the Currency converter link and compound interest calculator links from your Resource page to estimate the value of your investment in Thai Baht at the end of a five year investment.

Record your answer on a piece of paper and show to your teacher.

Figure 5.21. Online task 2 on the topic of interest.

The multiple-embodiment approach to teaching (Dienes cited in Biggs & Moore, 1993, p. 226) suggests that concepts are formed through a process of abstraction from concrete experience, and the more varied that experience, the more powerful would be the concept that is formed. Our attempt in presenting the concept of compound interest in a variety of face-to-face and online tasks aligns with this multi-embodiment approach.

After completing the online activities in the session students were asked to email their responses to Cathy from their WebCT home page. Later students returned to their desks and worked in pairs and practised solving paper-based questions from the exercise sheet (Appendix 14). Cathy and I circulated in the class to clarify and assist students with interpreting the problem from the context and applying relevant mathematical processes.

5.4.4.1 Reflections and Interpretations

Observations from sessions covering the topic of simple and compound interest revealed that the treatment group class attendance pattern was settling into a trend with a core group of students attending the class regularly. They had become familiar with Cathy’s teaching style and the blended learning format involving online activities.

Students seemed to have settled into peer groups and helped each other in solving problems. During these sessions more able students from the class began to show active participation and readily volunteered to come up to whiteboard and solve problems for the whole class to see. However, female participants from the class were reluctant to come up to whiteboard and were content with providing verbal responses. Cathy's approach in solving the problem on the whiteboard with assistance with students conformed with Herbel-Eisenmann and Breyfogle's (2005) description of funnelling where a series of classroom dialogue between a teacher and students helps students to converge their thinking and understanding towards a predetermined path of thinking. Although transcripts of teacher-student dialogue were not used as a instrument of data collection, classroom observation notes for the session indicates a funnelling approach:

> Transposing equations explained using the whiteboard. Cathy wrote notes about methods and procedures to be followed when solving transposing problems. Students pay attention to the explanations and take notes on sheets distributed earlier in the class. Cathy continually seeks responses from students and provides them prompts to guide their thinking for the correct solution. It appears that students understand this method of teaching and recognize the need of taking notes from the board –especially solutions being explained.
> [Class observation notes: Thursday 2 August 2001]

While this method of teaching appeared effective with more able students, weaker students who had gaps in their understanding of decimals and percentages were finding it difficult to extract information from worded questions to apply it in a given formula for simple and compound interest calculations. More able students assisted these students in class and both Cathy and I circulated to provide one to one attention to students who needed help. At this point we also indicated to students that they could receive additional practice on these topics from online learning resources available from their course home page.

Accessing the course website and working on computers during their mathematics class had become a routine by now and students were able to log on to computers and access the course website without any difficulty. After discovering that some students in class needed extra practice with fractions, decimals and percentages topics two new links were added to the resource page after the first session and students were advised to access these online learning units to brush up their skills.

The use of the online tool for calculating compound interest from the Webmath website proved a successful strategy in clarifying the concept of compound interest as it simulated the calculation for each period as shown in Figures 5.17, 5.18 and 5.19. Students were able to try solutions of a number of problems in a short time and see how a general formula can be developed.

The online calculator for compound interest calculator did the multi step interest calculation in an instant and allowed students to focus their thinking on comparing the results produced by following the long method and the formula based method. It was obvious to us that using pen and paper for long method calculation of compound interest calculations students would have been able to solve hardly one problem during the class but with the online tool for the same calculation it was possible to demonstrate the complete method and give students time to practice and see for themselves how the formula for compound interest calculation is evolved from a long hand calculation. Many students commented during interviews that the pace of teaching was too fast for their liking and they did not have enough time to absorb new concepts. One student commented:

> *There's a lot of work and very little time to do it so that's a bit…Yeah students who don't do maths, don't like maths, they should have extra time on it, stay with it, so they can actually understand what they're doing.* [Interview transcript: student – Donna]

The issue of the pace of lessons and time spent on particular topics came up consistently in discussions with students and Cathy. Especially those students who were returning to study after a gap of a few years wished that we spent more time on each topic but course content and design demanded that Cathy covered all the learning outcomes within a given timeframe. This was a dilemma for us and one intention of using online resources in blended format was to make classroom learning more flexible and extend it beyond formal contact hours. We were expecting that with the teacher's guidance students would be able to make use of opportunities offered by online mathematics units via the

MCA website and the course home page. One student summed up his feeling about the pace of teaching as follows:

> *At the two week period I start to feel confident a little bit in it but all of a sudden I've got a test and then I feel like we're into a new topic and it's gone…I'm just starting to get interested a little bit, get the feel for the topic then we're into something different, which I've heard of before but can't remember…Or even two six month units cos…I think it's important to cover everything, everything that we've done. I see the relevance and I see how it works, and I think 'no you couldn't really skip that, this is really important' especially all the depreciation stuff, if you were trying to run a business you've got to understand what's happening in the market. So, do the algebra over four or five weeks cos I found that was just the grounding, and then everything a little bit longer.* [Interview transcript: student – Jacob]

During the online session all students showed a keen interest in solving their simple and compound interest problems with the help of online tools and working in pairs proved helpful as students were able to help each other with aspects of technology. Using online tools required that students were able to identify different variables of a problem and use correct entries for input fields. We encouraged them not to accept the computer output blindly. During use of these online tools Cathy and I emphasised the need for estimating answers and applying the criteria of reasonableness to output provided by online tools. After initial trial and error methods students grew in confidence and were able to use the online tools effectively. They also realised that online tools have limitations and as users of these tools they had to work on some problems manually before applying online tools.

Students raised the issue of relevance of online activities to the assessment task, as they were keen to know if they would be assessed using online activities. It was a sticky issue for Cathy. On the one hand she knew that using online activities were encouraging students to engage with the content and were helpful in building confidence and motivation but on the other hand she appeared apprehensive about fairness of testing students using online activities when control group students were being tested using standard print-based tests. I shared her view regarding fairness and we decided to give only print-based tests to both treatment and control groups. Although the treatment group students used the online tools to work on interest problems keenly their subsequent engagement with online resources was limited and only seven students posted their answers to online activity on interest calculations on the WebCT. Others chose to focus on practising paper-based problems in preparation for the test.

5.4.4.2 Assessment

At the end of two weeks of work on the topic of interest students were given a paper based assessment task in the third session (Figure 5.22). The paper based assessment task comprised four worded problems including both simple interest and compound interest problems. As for previous units, two sets of assessment tasks similar in difficulty level were used to ensure that students worked individually and there was no chance of copying from each other. No online activity was included in the assessment and both control and treatment group students completed the same paper based assessment task as shown in Figure 5.22.

Assessment Task

1. Find the amount of interest earned if $6250 is invested at 4% p.a. (simple interest) over 6 years.
2. What principal will amount to $17250 if it is invested for 2 years and 6 months at 6%p.a. (a) simple interest (b) compounded quarterly.
3. How long will it take a principal of $4500 to double if it is invested at 6% p.a. simple interest?
4. Find the interest earned if a principal of $7380 is invested at 5%p.a. compounded quarterly.
5. How long would it take a principal of $6500 to amount to $9621.60 of it is invested at 8%p.a. compounded semi annually?
6. A principal of $6000 amounts to $7622.94 when invested for 4 years with interest compounded monthly. What is the annual rate of interest?

Figure 5.22. Paper based assessment task on the topic of interest.

Results from the paper based assessment for the topic on simple and compound interest appear to be similar in comparison (Table 5.8). The mean and median scores of control group students were slightly higher (42.86 / 41.67) compared with treatment group mean and median scores (39.29 / 40.70) but overall the two groups showed very little difference in assessment results. It is interesting to note that less than 50% (10) students from the treatment group took this test whereas for the control group students the attendance was nearly 75% with 12 students taking the test.

Table 5.8
Comparison of interest test scores

	No. of Students	Mean Score	Median Score
Treatment Group	10	40.7	39.29
Control Group	12	42.86	41.67

When results of only those students are counted who made it until the end in both groups, it appears that on the topic of interest control group students achieved better scores because five students from this group achieved scores above 75% whereas in treatment group only two students managed 75% or above. It can be argued that this core group of regular students from the control group were able to handle the assessment task on interest with greater success and which may be attributed to their focused work on paper based tasks and greater peer to peer and peer to teacher interaction in the traditional mode of teaching. In contrast the treatment group students who learned new skills in manipulating and working with online tools to solve interest based problems appear to have missed out on mastering paper-based skills in solving these problems. Cathy acknowledged this concern at different times during the course that if we ask students to work with online activities it may put them at a disadvantage in paper-based assessment because she felt that the nature of the mathematics changes with the medium of instruction and our assessment practice needed to reflect this change (Booth et al., 2003; Oliver, 2004).

5.4.5 Topic 4: Depreciation

The topic of depreciation was introduced after work on percentages and simple and compound interest had already been done with both the control and treatment groups. Learning outcome statements for this topic suggested that students learn about depreciation of asset value and be able to calculate depreciation rates using the straight-line, reducing balance (diminishing-value), and units-of-production methods. Face-to-face teaching session included explanation of relevant concepts and formulas and their application in solving given problems. Similar to previous topics Cathy used a number of examples and solved them on the whiteboard applying cognitive apprenticeship principles and the funnelling technique in leading students' responses to the desired path of action. The use of straight line and reducing balance methods in calculating depreciation offered Cathy an opportunity to incorporate the use of Excel on computers. Since students had learned Excel as part of their computing modules in the previous semester students readily agreed to work on Excel and apply their skills in solving mathematics problems. Typical problems given to students included questions like:

- Using the straight line method of depreciation, for an asset with an original cost of $12,000 and an estimated life of 10 years
    a) Find the annual amount of depreciation
    b) Find the annual rate of depreciation
    c) Prepare a depreciation schedule for the first 4 years

- An asset costing $10,000 has an estimated life of 7 years and is depreciated on a reducing balance method at 13%pa.
    a) What is the asset's book value at the end of the fifth year?
    b) Prepare a depreciation schedule

After the teacher led session students were given a worksheet (Appendix 15) for practice exercises where they could apply the methods shown to them by Cathy in solving problems.

During the online session students were introduced to the Business section of MCA Online website where questions and answers from past papers were explained and solved. Students were also shown the Ask Dr Math archive of questions and answers related to the topic of depreciation. We also used a link to a depreciation online calculator from the Resource Page available at WebCT course website. Students were shown how to use this calculator to solve straight-line method depreciation problems. Later in the session students were given two online tasks. In one task students had to use Excel to prepare a depreciation schedule for given problems. This depreciation schedule had to be saved as an Excel file and sent to Cathy by email. Students were asked to use the WebCT mail option to post their work to Cathy.

In the second online task students had to explore Internet based tools for calculating depreciation problems. It was an investigation task where they had to find appropriate online calculators and test them to see if they were suitable for solving problems given to them in their exercise sheet. It was a problem-solving situation where students had to establish if they could rely on the online calculator selected to give them reliable solutions to their depreciation problems. These online activities were presented to students as assessment tasks and they were required to email and post their responses on the discussion board of WebCT by the following email.

5.4.5.1 Reflections and Interpretations

During the two lessons devoted to the topic of depreciation attendance for the treatment group was at it lowest for the semester. Control group students also registered their lowest attendance for the second lesson on this topic. Explaining the possible reason for low attendance Cathy suggested that two teachers from the department were leaving for overseas teaching assignments in China and they had given a load of assignments to students to cover their courses before leaving. Students were under stress of meeting deadlines for these assignments forcing them to miss classes. The assessment task for depreciation was done in an online mode where 10 students completed their assessment tasks online. In control group assessment was paper based and eight students took the in-class assessment task.

The treatment group class engagement with online activities was more evident during this topic and this may be directly associated with the fact that they were told that assessment for this topic was going to be in an online format. Eight students posted a total of 18 messages on the discussion board. These messages contained answers to problems students were asked to solve. Interestingly, more than half the postings on discussion board were made outside class hours indicating that students had become more confident in using the course website from their homes and were prepared to use the online tools when it was part of a required task.

In face-to-face sessions students had learned how to use the formula for calculating depreciation by the reducing method. The formula required manipulation of the inverse function on a calculator. Cathy had also shown the use of log tables to solve inverse problems where the period of depreciation years had to be calculated. More able students in the class were able to learn to use the formula quickly but students who had not learned mathematics in their senior secondary years and a couple of mature age students needed assistance from Cathy to solve these problems.

Later, when online calculators were used to solve the same problems students appeared relieved that there is another short cut way to solve these problems. However, the task of finding a relevant depreciation calculator from a jungle of online calculators to solve financial calculations required students to interpret information provided on the calculators and relate it to the problems they had to solve. One student noted in his interview that the use of online calculators to solve financial calculations provided him a kind of security. In response to a question whether the computer and Internet use in the class made learning of mathematics easier, he pointed out that:

> *A lot of the stuff I can understand in my head but I don't know how to apply it but to click on the resource page and have those special financial calculators and those special tasks that we can do, solidifies that information in your mind, you see how it works, you do a few more examples and you think 'even if I get stuck I can always come back here', and use these to check my answers. It's a security almost.* [Interview transcript: student - Juang]

Although the use of online calculators to work out depreciation problems appeared to be an easier option, students needed assistance in learning what different input fields on the online calculators meant and how to interpret depreciation problems when using online calculators.

5.4.5.2 Assessment

Treatment and control group students completed different assessment tasks for the topic on depreciation. They were given similar problems to solve but while control group students completed a traditional paper based test consisting of four problems, the treatment group students worked on computer based tasks requiring use of Excel and an online task of locating and testing online calculators to solve depreciation problems. By this stage of the module we were beginning to realise that the use of online activities in our blended learning approach was affecting the content and nature of mathematics learned. Using the tools available to them students were feeling the freedom to explore solutions by in-putting different values and seeing their effect on the outcome. We encouraged them to do this as we thought that it helped them understand the relationship between different variables. In contrast to the paper-based solution where students focussed on the process of solving the problem using a given algorithm, students in the online group used online simulation calculators to explore solution of problems by observing the effects of different input quantities on the results produced.

While 88% of the control group and 100% of the treatment group students passed this assessment they used very different methods to solve their problems. The control group students used a formula-based approach where they substituted the given values in a given formula and solved the algorithm for the unknown quantity. This method allowed them to focus on the process of substituting values in an algorithm and solving the equation. However, the assessment task given to the treatment group students made use of technology to solve these problems and allowed students to explore the relationship between different variables.

While the assessment task set for the treatment group allowed them to gain the skills of using online tools and explore various calculations for depreciation of assets, we found it challenging to evaluate students' responses to this task and award them appropriate grades for the assessment. In a traditional assessment it is rather easy to look at the solution presented by the student and award marks for correct procedures and calculations, but in an online activity the issue of marking an assignment takes a new dimension, especially if the activity involves problems solving and exploration. For example, in the online assessment task requiring students to search and locate an online depreciation calculator and use it to solve the problems given in the exercise sheet it was important for student to find and use a calculator that was appropriate for the problem they were attempting to solve. From the assessment point of view, while it was easy for us to check if the students had located an appropriate calculator from their email message in which they had to provide details of the online calculator, the actual use of the online calculator by the student was difficult to assess because the output was in an online format and could not be copied and sent to the teacher via the email message. Students had to copy and paste data from online output, which was difficult to interpret in an email due to formatting problems. As a result, for the assessment of online tasks on depreciation we relied on a set of criteria based on relevance of students' selection of the online calculator and if the final answer provided by their online calculation was correct for a given problem.

5.4.6 Topic 5: Linear Equations

Linear equation and graphing techniques topics were the final two topics for the module. These topics were taught in the last two sessions and a paper-based assessment on linear equations was conducted in the third week. Graphing techniques were assessed using Excel program and students were asked to submit an assignment on graphing work. The learning outcome required the class to be able to plot and interpret straight-line graphs, apply them to business decision-making and discuss the significant features of non-linear graphs.

Class attendance for both groups had settled by this time and treatment group attendance ranged from 11 to 14 while control group attendance ranged from 6 to 9. The topic was introduced with a drawing of Cartesian plane on the white board and showing how ordered pairs are located on this plane. Cathy used examples from her exercise sheet to demonstrate the method of solving linear equation graphically. The concepts of gradient, y-intercept and the general form of linear equation in terms of $y = mx + c$ were introduced on the whiteboard using examples for expense and income equations. After some discussion on the application of the graphical methods of solving business problems of income and expense to carry out break-even analysis, students were given an exercise sheet (Appendix 16) for practice and practical investigation during the online session of the lesson.

In the online session activities were designed to provide interactive practice of linear graphing using an online simulation. During the face-to-face session Cathy had realised that the class needed some background skills in graphing techniques and working with coordinates. She directed students to a link from their WebCT course resource page. This link opened in a new window and allowed students to key in coordinates and see how these coordinates can be joined to draw lines on a graph (Figure 5.23). Students used the coordinates given to them in the exercise sheet to practice with this interactive online tool. This Java based online tool proved very helpful for students who had little or no familiarity with how coordinates are located on a mathematical graph.

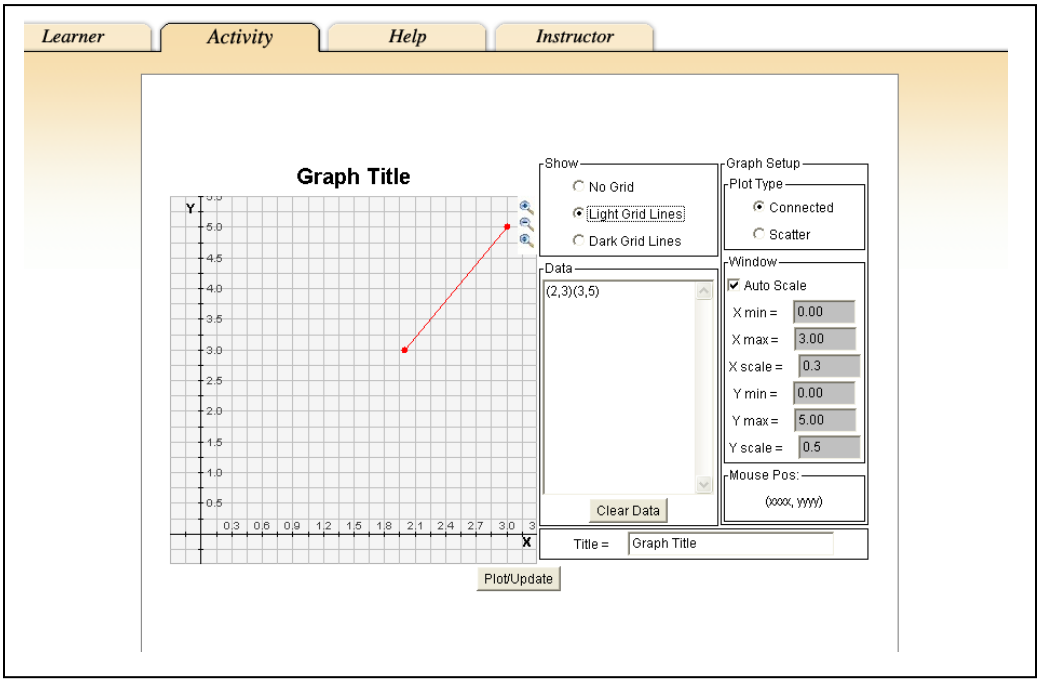

Figure 5.23. Interactive coordinates plotter.
Source: http://www.shodor.org/interactivate/activities/SimplePlot.

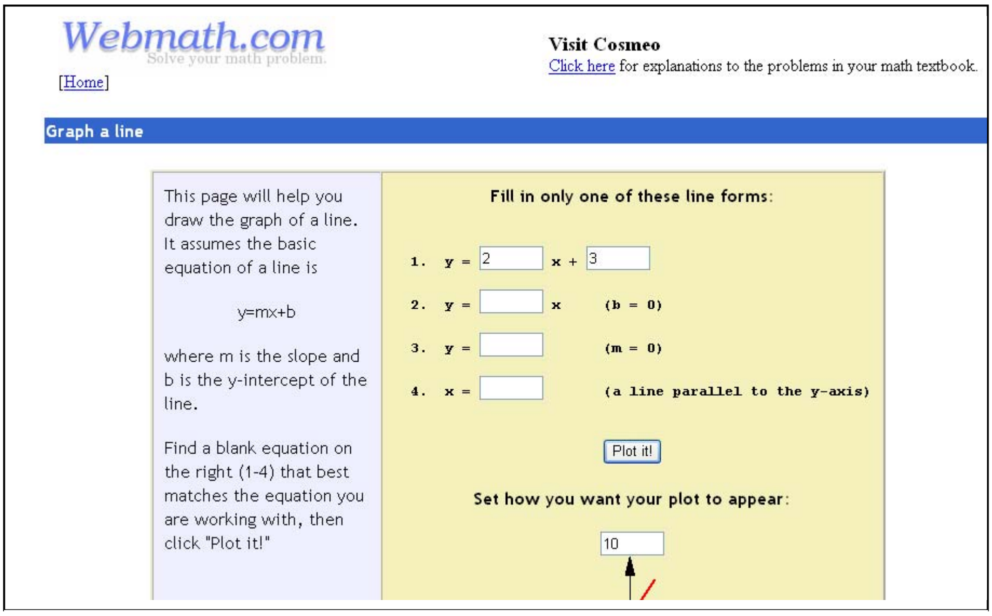

Figure 5.24. Online tool for graphing a linear equation.
Source: www.webmath.com.

After exploring the topic of linear graphing from the resource page links students were given an online activity. This activity asked students to use linear equations derived from income and expense problems to plot a graph. An online tool from Webmath.com was made available through the Resource page (Figure 5.24).

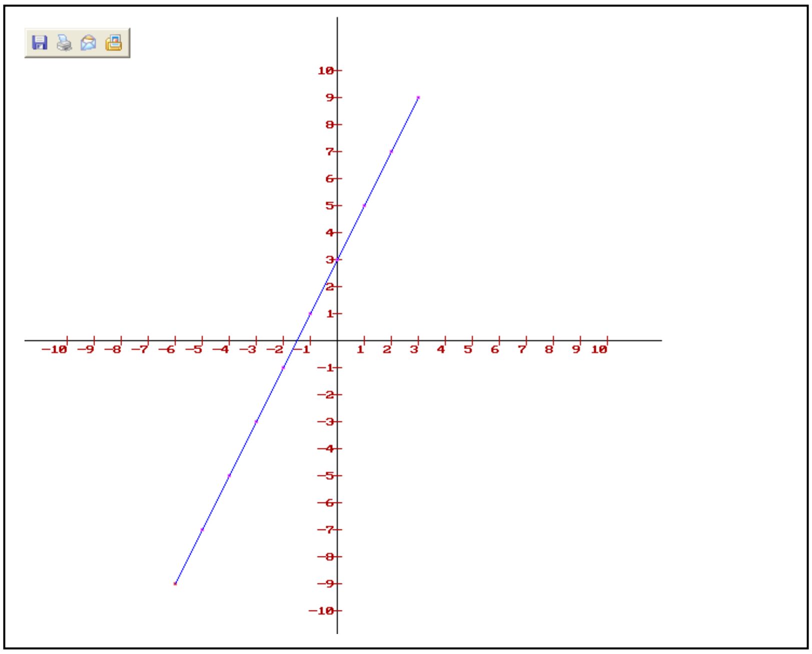

Figure 5.25. Graph of a linear equation.
Source: www.webmath.com.

In this online activity students had to input *m* and *c* variables for a $y = mx + c$ equation to plot a graph for the equation. The java applet created a graph for the equation instantly and in follow up discussion students were prompted to play a game where one student would key in an equation to plot the graph and a partner would look at the graph to guess the algebraic expression of the linear equation.

This online tool for linear equation graphing allowed students to choose a range for their *x* and *y* axis thus allowing them to draw graphs for equations from realistic business problems where numbers were larger and required larger scale ratios for graphing. After the online session students were asked to work with graph paper and draw graphs for linear equations to solve for breakeven analysis. This activity was followed up in the following session where students worked on break-even analysis problems without the use of online tools. The assessment task for this topic was based on a paper based activity and both control and treatment groups did similar tasks.

5.4.6.1 Reflections and Interpretations

I noticed that there were two groups of students in the class, those who had some familiarity with linear equations and graphical methods mainly due to their prior exposure to these skills in a VCE mathematics course and those who had no familiarity with graphing techniques. Considering this divide of those who know and those who don't, we searched the Internet for graphing tutorials and located a Java-based interactive tool. A link to this tool was added to the MCA Online website and the course resource page on WebCT. The use of embedding links to learning resources relevant to a problem-solving task illustrates how online learning environments can be created for anchored instruction (CGTV, 1992).

The interactivity of the online graphing activity made it interesting for students and they took part in the activity keenly. In particular those students who had little or no prior experience of plotting graphs learned the skills of locating *x* and *y* coordinates on the graph and had a visual experience of the representation of an equation into as a linear graph. The availability of this online activity to help students understand the process of drawing and interpreting linear graphs shows the usefulness of digital technologies in creating interactivity and multiple representations to advance our understanding of difficult abstract concepts (Goos, Stillman, & Vale, 2007) .

During a session when Cathy asked students to work on graph paper I realised that some students in class did not have graph papers with them and Cathy also had not brought any to class. Using the Internet, a number of grid papers for graphing were quickly located and their links were posted on the course home page. Students used this link from their course home page to print off the graph whenever needed. During the second session on linear equations, the computers failed to log on to network and our course website was not accessible. This incident provided an opportunity to Cathy to devote the full session to solve problems on break-even analysis using graphical methods. Students used a pen and paper method to draw graphs for cost and expense equations. One of the difficult parts of graphing for students was use of an appropriate scale for plotting given equations. We noted that the online activities were also limited in allowing students to manipulate scale factors for practice purposes. This led to a trial and error approach by students.

The online tasks for this topic were designed for practice and exploration purposes only. They were not included in assessment for the topic and students had to participate in a paper based test for assessment of linear equations. As there was no requirement to post answers or comments on the discussion board students stayed away from using the discussion board and only two postings were made by students. These related to queries related to other topics and showed that some students had become familiar with using the discussion board from their homes.

5.4.6.2 Assessment

The assessment task for the topic of linear equations was in print based format only (Figure 5.26). No online activity was included in assessment of this topic and both treatment and control groups completed the same assessment activity. The assessment task required students to solve the following questions using a grid paper provided along with the assessment task.

Assessment Task

1. Given the equation $y = 4x + 8$; a. state the y intercept, *b*. state the gradient, *c*. sketch its graph
2. Solve the following simultaneous equations graphically.
   $y + 2x = 8$
   $5y + 2x = 20$
3. The total cost of manufacturing radios is linear. The radios are sold at $150 each. When 10 radios are produced the total cost is $4500.
   a. Sketch the cost graph (on the graph paper supplied)
   b. Use your graph to find the fixed cost
   c. Find the variable cost per radio
   d. State the cost equation
   e. State the income equation
   f. Sketch the income graph (on the same axes as the cost graph)
   g. Use your graph to determine the number of radios that should be produced and sold to break even.

Figure 5.26. Paper-based assessment task on the topic of linear equation.

An examination of comparative results from assessment reveals that the two groups achieved very similar results as mean and median scores for two groups were very close (Table 5.9).

Table 5.9
Comparison of linear equations test scores

	No. of Students	Mean Score	Median Score
Treatment Group	11	40.90	50.00
Control Group	7	39.29	50.00

Although the results from the assessment task for the topic shows that there was no difference between treatment and control group performance, as measured by print based assessment tasks, from our conversations and reflections about the class both Cathy and I agreed that teaching of coordinates and graphing had been made easier to understand with the help of online graphing tools used in the practice activities with the treatment group.

5.5 Conclusion

This chapter has reported the details from the second cycle of this research where the online learning environment developed in the first cycle was customised for teaching a business mathematics module in a blended learning format. This second research cycle aimed at designing and implementing a teaching program where classroom learning of mathematics was carefully blended and enhanced with web-based learning activities relevant to the content of the course.

A blended learning approach adapted in the second cycle allowed for online activities to be integrated with pen and paper tasks in lessons. This approach allowed for blending of face-to-face teaching with online resources and activities. It also allowed for blending of teaching methods where traditional teacher led instruction was blended with online learning methods based on tasks and activities using interactive simulations, online tools, discussion board and email. A number of conjectures guided the design of the learning environment in the second cycle. These conjectures were based on the outcomes of the first cycle of this research and included ideas such as that learning in mathematics can be supported more effectively if we present the vocational course content in the face-to-face mode supported with resources and activities located in an online learning environment. We also expected that the use of a blended learning approach using would lead to an improvement in students’ attitude towards mathematics and their performance would be better than those learning through traditional teacher directed instruction only. During this research cycle we hoped that the use of online tools and authentic data from the Internet would have a positive effect on students' participation and engagement in class activities and their mathematics learning would be enhanced. We also anticipated that the use of discussion board as a communication tool during the course would help in peer-to-peer and teacher to student interaction and sharing of knowledge and information.

Observations from classroom implementation of web-based learning activities and analysis of data from WebCT and assessment records reveal a complex picture of students' participation and engagement with the learning content. They also point towards a range of technical and pedagogical issues the teacher has to deal with when introducing online learning in a mathematics classroom. Observation of classroom practice showed that the teacher's use of online activities extended and expanded the scope of learning but traditional pen and paper assessment methods were not suited to assessing learning that occurred in the online mode.

The next chapter presents a detailed analysis and interpretation of observations and data obtained during the second cycle of the study to verify our conjectures and to respond to research questions regarding students' access to and use of online environment and their participation in online learning, the effect of blended online learning on students' attitude and achievement, and how a mathematics teacher's role is affected by use of an online learning environment in teaching.

Chapter 6: Practice Interpreted

6.1 Introduction

This chapter is an account of the analysis, interpretations and assertions emerging as a consequence of retrospective analysis of both qualitative and quantitative forms of data obtained during the design and enactment phases of the second cycle of this study. As suggested in design-based research literature, one of the primary aims of conducting retrospective analysis is to locate the design experiment in a “broader theoretical context” and create situated accounts of learning that relate learning to the means by which it can be supported and organised (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). In providing the analysis and interpretations an attempt is made to connect findings with conjectures made earlier in design and enactment stages while responding to research questions set forth at the commencement of this study. Sections of this chapter follow a similar pattern in which the relevant research question is restated followed by a list of conjectures drawn in relation to the issues being investigated and presentation of findings and discussions.

In section 6.2 issues related to student participation in blended online learning are presented and discussed. Factors affecting student participation are discussed in the context of personal, online design and course design issues. Section 6.3 covers the topic of access and use of online environment by students and attempts to highlight findings related to Internet access, online communication and the role of computer skills in learning mathematics in an online environment. Section 6.4 focuses on the role of teacher in blended online learning. The teacher’s role is discussed in terms of pedagogical, social, managerial and technical dimensions and how they were affected in a blended learning environment. Sections 6.5 and 6.6 present findings related to students’ attitude and achievement from pre-test and post-test measurements and Section 6.7 discusses assessment issues in blended online learning of mathematics.

6.2 Student Participation

One of the research questions in the second cycle of this study aimed at exploring issues related to student participation in online learning within a blended learning format. Student participation was considered as their attendance in face-to-face sessions, access count on the WebCT home page for the course, engagement with online activities, completion of assessment task requirements and postings on the discussion board.

The conjectures drawn regarding student participation in the second cycle of this study proposed that:

- Blended learning would lead to improved learning and retention of students because those students who are unable to attend particular face-to-face sessions would be able to continue with the module and participate in learning activities.
- Use of authentic data from the Internet would affect student attitude towards mathematics positively and their engagement with class activities and mathematics would be enhanced.
- Navigational scaffolding in the online design would keep a student focused on a particular learning path and avoid distractions resulting from browsing external websites.

In terms of class attendance student participation followed a similar pattern in both treatment and control groups as described in Chapter 5.4.2.1. Student numbers dropped during the first six weeks of the course from both the treatment and control groups and it appears that there may have been a range of factors at play that affect attrition rate at TAFE level courses generally. A literature search conducted by Gabb, Milne and Cao (2006) shows that likely factors that influence attrition at TAFE and higher education courses include prior academic achievement, course preferences, course fit, quality of teaching, language background, parental education and blending work and study. However, in this study our goal was more specific and our analysis focused on identifying those factors that influenced students’ participation in blended online learning activities. Studies in online learning in the higher education sector have shown that learner readiness and course design factors directly affect learner participation in online learning (Gunawardena & Duphorne, 2001; Harasim, Hiltz, Teles, & Turoff, 1995; Swan, Shea, Fredericksen, Pickett, & Pelz, 2003). Similarly, effective presentation and organization of content in the online learning environment is also known to be an important factor in encouraging student participation in online learning. It includes interface design factors such as screen design, navigation, interactivity and feedback (Mihalca, 2005). During the second cycle of this study factors affecting student participation in blended online learning of mathematics in a vocational education context were investigated from the perspective of learner readiness factors, interface design factors and course design factors.

6.2.1 Learner Readiness Factors

Learner readiness factors have been identified as personal factors such as students' learning preference, prior learning experience, computer skills, interest in the course content, learner attitude and motivation (Gunawardena & Duphorne, 2001). A number of these factors affecting students' participation in blended online learning came to our attention during class observation. One of the most important factors was students' computer skills and prior experience of the Internet. Warschauer (2003) notes that learners display varying abilities to make maximum use of online technologies. He points out that students' ability to make effective use of online technologies is not necessarily an issue of access to technology and hardware and asserts that students' computer literacy and familiarity with the online medium are more important for their effective participation.

In the second cycle of this study we noted that students' previous knowledge of the Internet, browsers, online navigation and experience of discussion forums and online chat were important factors in their online participation. But, for many students it was their first experience of engaging with computers to do mathematics and those who had low competence levels in working with computers had to find help and spend relatively more time attempting online activities. These students with low confidence level with computers needed a lot of encouragement and support from teachers and their peers to participate in online activities. On the other hand students with prior experience and skills in using computers appeared to demonstrate greater readiness to participate in online activities. In some cases, however, students' attitude and motivation played a greater role in their participation in online activities and despite their readiness and computer skills they remained less active participants online. As an example one student in an interview session reported that:

> *You can't always use the Internet for maths because you need a person up there explaining on the board, putting in the quotations and everything, it's better. The internet hasn't just got much things, it's just got information that's it, you need some examples, you need a person. ...I've been longer, I've been using the computer, internet for longer but I've been using chat. I do a lot of infoteching around, it's easier for us*. [Interview transcript: student - Zoe]

This comment highlights the issue of preconceived notions about learning mathematics and confirms that the use of computers in a mathematics class is not always seen as a positive thing by participating students, although most students, both active and inactive in terms of online use, agreed that online activities in the business mathematics module was a positive change.

Another personal factor playing an important role in students' participation in the blended online learning was students' attitude towards mathematics. Many students started with a very negative attitude towards mathematics as shown by measurements collected using Aiken's Mathematics Attitude Scale. A detailed comparative analysis of the effect of blended online learning on students' attitude towards mathematics is presented in Section 6.5 however this section focuses on the effect of students' attitude on their participation in blended online learning.

Nearly half the class who took the attitude pre-test obtained a negative score on a scale of –20 to +20 showing that many students in the treatment group did not have a liking for mathematics as a subject. One mature age student showed clear signs of "mathematics anxiety" and reported in interview that:

> *I go weak at knees at the thought of having to do that (maths). I never thought I'm that bad as I'm going in the subject, like I never needed to have to do that, I can't remember ever doing this what I'm doing in this maths subject so it's a new world for me. [Interview transcript: student.- Peter]*

This student had a score of –20 on the mathematics attitude scale but despite this apparently negative feeling about mathematics his participation in online activities as measured by access to WebCT count was quite high at 115. He struggled to do class work throughout the semester but stayed on to achieve a minimum pass (see Table 6.2). Similarly, another female student from this group who was active in online participation with the highest WebCT access count of 144 visits also scored low on her mathematics attitude. In her interview she also reported that she "gets really scared" with mathematics. These students show that despite their poor attitude towards mathematics, in actual practice they were quite keen to take part in online learning activities.

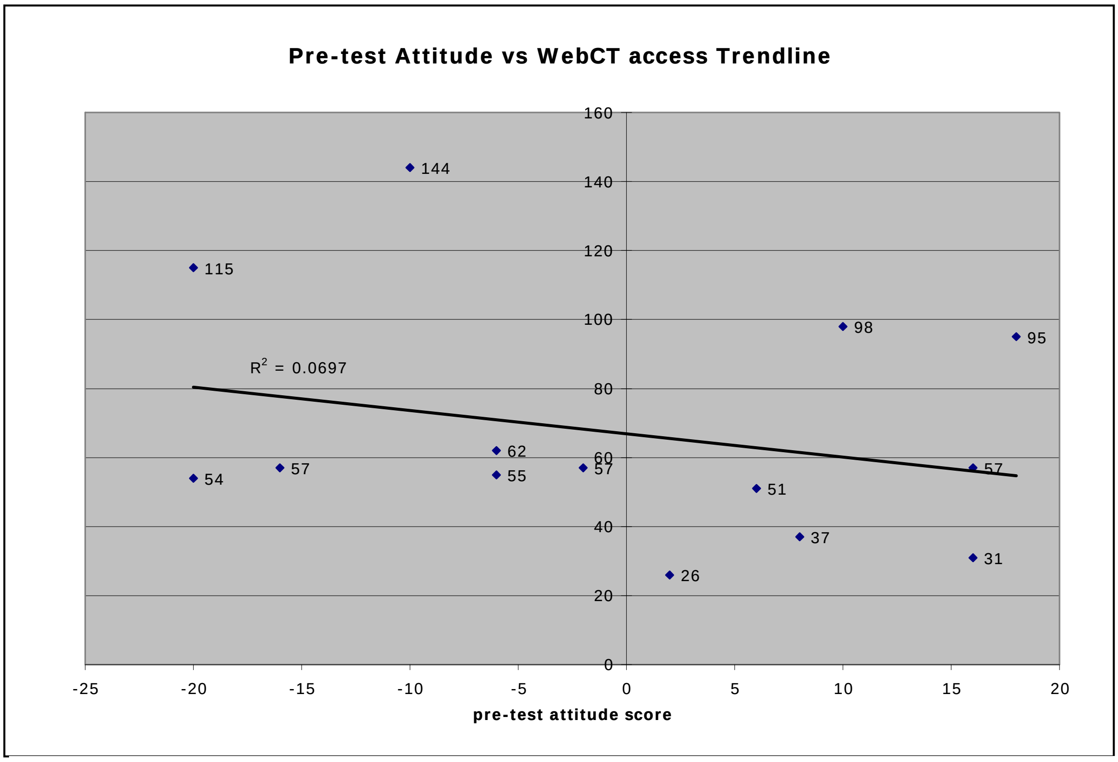

Figure 6.1. Scatter graph and trendline of WebCT access count of students compared with their pre-test attitude scores on Mathematics Attitude Scale.

Correlation between students' pre-test attitude scores with their online participation in terms of WebCT access count produces a relatively weak (Pearson's r = -0.26) association between these two variables showing that online activities were not related either positively or negatively by students' attitude towards mathematics. As shown in the scatter graph (Figure 6.1), students with relatively high attitude scores were not the only ones active with online learning. In fact, some students who had shown negative attitudes towards mathematics appeared to show greater participation in accessing and using online activities. This correlation between pre-test attitude score and WebCT access count was calculated using scores of all students who were present at the start of the course and had taken the pre-test attitude test.

Based on their WebCT access count students were grouped into more active and less active online students. Students who reached a WebCT access count of greater than the median score of 57 were listed as more active online students and those who scored 57 or less were listed as less active online students (see Tables 6.2 and 6.3). A comparison of mean scores reveals that more active students achieved better results in the final achievement test compared to less active students. However, in terms of attitude there was a greater improvement in attitude of less active students as shown by their mean score improvement from –3.2 to 7, even though the mean achievement score was a mere pass (Table 6.1).

Table 6.1
Mean scores of treatment group students according to online participation

	WebCT Access Count	Pre-test Attitude	Post-test Attitude	Attendance	Final Achievement Test Score
More Active	103	-1.6	1.2	87	70.8
Less Active	55	-3.2	7	90	53.4

When seen in the context of overall participation and final achievement scores, students with a positive attitude score seem to have accessed and participated in online activities and achieved better than average results in their final test whereas some more active online students with a negative attitude score towards mathematics despite their greater participation in online activities barely passed the module as shown in the Table of Performance for More Active Online Students (Table 6.2).

In comparison, most of the less active online students had obtained a negative score on the attitude towards mathematics scale in their pre-attitude test. As shown in Table 6.3 there was very little variation in the WebCT access count of less active online students and it appears that they had accessed the course website only from the class as part of online activities during class sessions.

Table 6.2
Individual Performance of More Active Online Students

	Attendance %	Online Participation			Attitude		Achievement	
		WebCT access count	Articles read	Total posts	Pre-test attitude	Post-test attitude	Tasks passed	Final test score %
Donna	100	144	66	6	-10	6	4	50
Peter	83	115	46	6	-20	-20	3	50
Ngyen	100	98	59	13	10	8	6	86
Jacob	83	95	26	6	18	18	6	95
Tina	58	91	56	8	8	8	5	70

Table 6.3
Individual performance of less active online students

	Attendance %	Online Participation			Attitude		Achievement	
		WebCT access count	Articles read	Total posts	Pre-test attitude	Post-test attitude	Tasks passed	Final test score %
Abdul	75	57	32	2	-2	6	2	60
Zoe	75	57	28	5	-16	10	3	17
Sagar	100	57	29	5	16	16	4	65
Jim	100	54	29	5	-20	-15	5	50
Juang	100	51	26	8	6	18	5	75

However, one less active online student (Juang) with a positive score on attitude scale was able to gain 75% marks in the final test and though his access count to WebCT was lowest his participation rate in other aspects of online participation such as articles read, original posts and follow up posts was similar to one of the more active online students (Jacob) who also scored the best result in the final test. I think that student attitude towards mathematics played a less significant role in their participation in online activities but students with a positive attitude towards mathematics seem to have used the online access more selectively. However, it is clearly seen that negative attitude towards mathematics did not pose a barrier to participation in online activities.

Table 6.4
Correlation coefficient values for students participating in blended online learning (paired sample only)

	Attendance	Pre-test attitude	Post-test attitude	WebCT access count	Final test score
Attendance		0.237	0.196	0.210*	0.179
Pre-test attitude	0.237		0.788	-0.100	0.775
Post-test attitude	0.196	0.788		-0.159	0.329
WebCt access count	0.210*	-0.100	-0.159		0.076
Final test score	0.179	0.775	0.329	0.076	

* Correlation Coefficient was 0.783 when comparison between WebCT access count and attendance scores of all 24 students in the treatment group were used.

It appears that there was no association between students' attitude towards mathematics and their participation in online activities as evidenced by their WebCT access count. A correlation analysis of between WebCT access count and pre and post test attitude scores showed weak correlation values of –0.10 and –0.159 respectively (Table 6.4). It seems that not all students in the blended learning environment participated with the same enthusiasm and some students despite showing a 100% class attendance registered less than 50% WebCT access count compared with the more active online students (Table 6.2 and 6.3) resulting in a reading of weak association between WebCT access count and class attendance when correlation used paired sample scores only (Table 6.4).

However, when correlation between WebCT access count and attendance for all students who started this course was considered (Figure 6.2) it was found that the association between students' attendance and WebCT count was fairly strong (r= 0.783). It suggests that, generally, most students participated in the online learning environment fairly consistently but the rate of participation was not uniform and among regular students the distribution between active and less active online users was nearly equal (Tables 6.2 and 6.3). It also indicates that the blended learning environment in the class encouraged students' ongoing and consistent participation in online and WebCT activities.

Findings related to learner readiness factors point to the fact that although students' readiness to participate in online learning activities in mathematics requires them to have pre-requisite skills and confidence in computer use, these factors are not sufficient motivators for students' actual use of the technology in a learning environment.

Students appear to choose to use the online learning resources selectively. From this analysis it also appears that students' attitude towards mathematics plays a more significant role in their performance in achievement tests than on their participation in online learning environment. For many students, their active involvement in online learning did not produce improved results either in their attitude towards mathematics or in their final achievement scores suggesting that either we were unable to harness their skills and interest in computers towards enhancing their mathematics or our testing methods did not relate well to learning happening via computers.

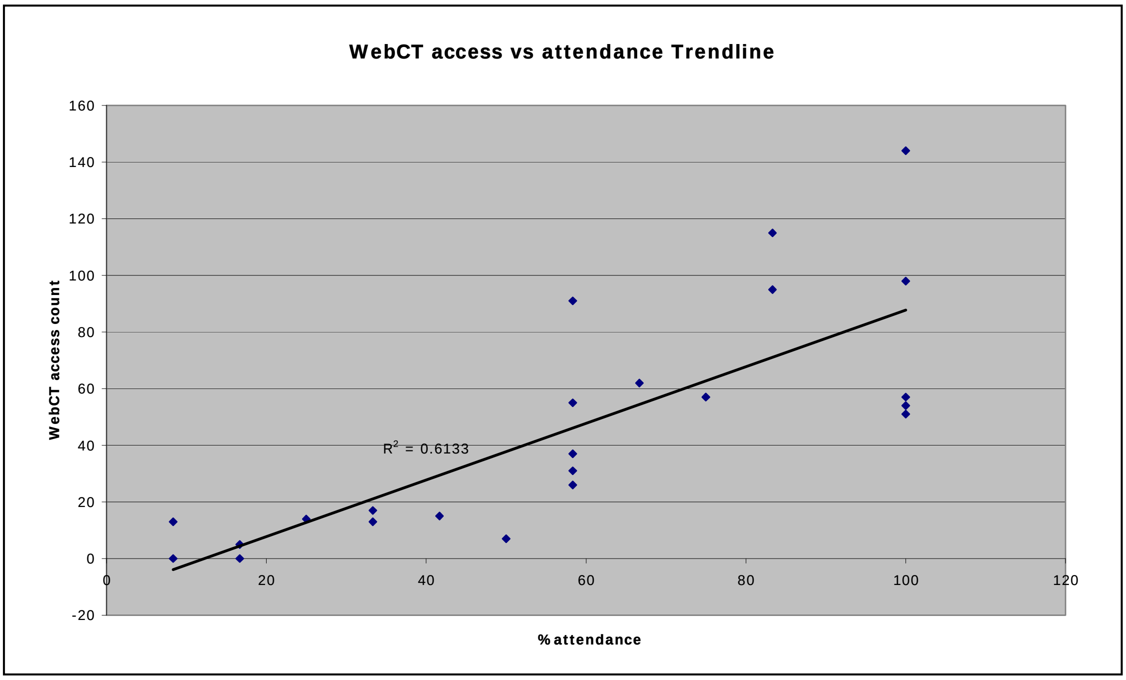

Figure 6.2. Access to WebCT home page compared with attendance in face-to-face class.

6.2.2 Interface Design Factors

This study involved the design and development of an online learning environment for mathematics and its use for supporting classroom teaching in the vocational sector. In this context the design experiment process allowed us to continuously tweak the design of our online learning environment. Research literature on interface design (Mihalca, 2005) and our observations and analysis led us to identify a number of design factors linked to participation of students with the online learning environment. These factors included navigational scaffolding, interactivity, authentic learning experiences and the blended learning model. During the design and enactment stages of this study a number of these design issues prompted us to draw tentative conjectures about how modifications in design might lead to improvement in practice and outcome. In the following section some of these conjectures will be contested and refined with support from evidence collected during the study.

Our design of MCA Online website and WebCT module home page drew on principles of anchored instruction where learning resources required for solving a problem are embedded in the learning environment and students have to explore and use these resources to solve given problems (CTGV, 1992). In this context navigational scaffolding refers to elements within the design of a learning environment which help learners find and access information and tools without being sidetracked or adding to their cognitive load (refer to section 4.2.2.). Through this approach of navigational scaffolding we hoped to keep students focused on a particular learning path and avoid distractions resulting from browsing external websites. Students' frustrations with unstructured use of the Internet as a resource are clearly indicated by the following extract from a student interview:

> *We use internet all the time in other classes but they're more like 'do research, go and find this information' and you've got to go and use search engines…I find that pretty boring and number one cos it takes a long time. But I think they'd be limited as to what they really is online stuff. You need some kind of structure. If they'd planned it and set it up as a weekly thing and followed the course outline and said 'this week we're doing this topic, look on the homepage and there's a few site to click on and read this article' and then 'put in a report on it' or something, or 'email me and tell me what you thought about it' that would stimulate me to go out and do the research. But I find a lot of lecturers 'just go and do a search' and you think 'I hate searching' because you go through so much information and you're unmotivated whereas I know if I go to the site here there's online tasks, the resources are on the page, everything I need is there usually or I'm shown how to do it even if I don't know, a little bit more motivation there I think.* [Interview transcript: student - Jacob]

Since we also relied on external Internet websites for our dynamic mathematics content it was prudent for us to plan our design in a way so that students could get direct access to this dynamic content. Usually, the actual dynamic mathematics content on a website is buried in deeper layers of the website and users have to navigate their way to the desired content by first making selections from the opening screen of a website. Observation of students working independently on websites had shown to us that finding relevant parts of a website that give you the necessary resource or tool was quite confusing and time consuming for students and many were distracted and became lost on these external websites. Both MCA Online and WebCT module design incorporated direct access to tools and resources from external websites and this navigational scaffolding proved very helpful for students. While doing trials for MCA Online enactment (refer to Section 4.3) and also while doing online activities with the treatment group (refer to Section 5.3) classroom observations of students' engagement on computers revealed that they were able to locate and use relevant tools and resources without being lost or distracted. In many cases the transition from their local website to a resource on an external website was so seamless that they were unable to differentiate if they had moved to another website on the Internet. The usefulness of navigational scaffolding provided by our module website was summed up by the same student as:

> *It's handy because realistically you get so much work and so many assignments that to get another piece of paper that we've got to take home and do in our books is a little bit lethargic and boring. But…jump on the net for few minutes, read through a couple of questions, utilise the resource page and stuff, it's a good change. And it's quite simple too to follow through...I think later rather than earlier I have understood how much it is able to help. Initially there wasn't enough emphasis on it, we knew it was there and we had a bit of a review through it but it wasn't until after we around I got in there and started playing around a little bit and looking at this stuff I thought 'all these resources, if only I knew they were here earlier it would've made my life a little bit easier'.*
> [Interview transcript: student - Jacob]

While students were able to access many dynamic websites and interactive content from external websites through a tightly controlled navigation and design, it demanded continuous monitoring of these links by Cathy and me and as designers for the course website we had to keep a constant track of changes in external websites and update required links. My experience and expertise of managing website content proved to be a crucial factor in keeping these links working for students.

Interactivity afforded by online activities ranks as another important factor affecting students' participation in blended online learning. Our conjecture regarding interactivity was that the interactive activities on our website will help in building students' understanding and use of mathematical concepts. Research findings indicate that interactivity is one of the key aspects of electronic technologies that enable a deep change in the experience of doing and learning mathematics (Kaput & Thompson, 1994, p. 678). Similarly, studies have also shown that interactive tasks with immediate feedback enabled the medium to engage students' attention for longer than usual (Laurillard, 1997; Mavrikis & Macciocia, 2005). Our online environment included interactivity in two forms. In one form students engaged with software generated simulations and problems where they were able to input data themselves and in the other form they engaged in online communication involving discussion board postings and email. In our design of the online environment we ensured that we had included both interactive skills practice exercises as well exploratory problem solving exercises (refer to Section 4.2.4 and Section 5.3 for detail of these exercises).

Observations from classroom practice indicate that the interactive tasks where the software provided students with immediate feedback had a positive effect on students' participation and their motivation to take part in online activities increased. It appears that immediate feedback from the software allowed students to take more risks in attempting the questions and using the guess and check method. Their increased motivation was evident from their active participation, increased social interaction with peers (sometimes to show them that they had done better or discovered something new). As an example during the first online activity on algebra transposition, once students had become familiar with the screen layout and navigation, they seemed to enjoy the practice where feedback was instant and they could monitor their progress. Delors, In'am, and Roberto (1998) point out that using the new technologies is also a way of combating under achievement because people who experience difficulties under the traditional system are sometimes better motivated when they come to use these new technologies and are thus better able to show where their talents lie. I noticed that students' motivation increased during the interactive online activity; perhaps it was because many students were able to experience success in solving equations using the technology. An entry from my class observation of this session reads:

> *This task proved a success in online learning as most students seemed to enjoy their participation and success in learning the task. Many students used pen and paper to help them solve the questions and self-scoring as a positive experience for most. A female student later reported that she liked this site and task very much and at home she helped her sister to practice algebra equations using this page. It appears that self-assessment part of online maths learning is welcomed by most students.* [Observation notes: Thursday 16 August 01]

The effect of interactive activities on students' participation was generally positive and most students appeared excited to interact with computers where they could see the consequences of their action in the form of some feedback.

The availability of and access to web resources enabled our design to include authentic learning activities using live and real data. We were able to design tasks that required students to seek information from real life sources and use them in solving problems. Use of banking websites (refer to section 5.4.3), use of live currency exchange rates during online activities on the topic of interest rates (refer to section 6.3.4) and use of depreciation calculators to work out salvage value and depreciation calculations (refer to section 5.4.5) provide examples of learning activities where face-to-face classroom work was extended with the help of online access to authentic data and information from real life resources. Although students in the class were working with problems presented to them in the traditional form of worded questions, the context within which these problems were located was real. In this way when students accessed and utilised online tools and resources to solve these problems, they were able to see the direct relevance of the mathematics learned to real life problem solving as noted by a student in his interview:

> *…I think it's important to cover everything (online activities), everything that we've done. I see the relevance and I see how it works, and I think 'no you couldn't really skip that, this is really important' especially all the depreciation*

> *stuff, if you were trying to run a business you've got to understand what's happening in the market.*
> [Interview transcript: student – Jacob]

For most students in the treatment group it was their first experience of doing mathematics activities in an online environment and they expressed mixed feelings about the usefulness of this approach. On the one hand we had students who were excited about using computers and the Internet to do mathematics activities and on the other hand some students showed reservations about using computers. I think that some students had a preconceived notion of learning mathematics and for them formal mathematics is doing serious work with pen and paper and solving questions using different techniques and algorithms. However, after a number of weeks of online activities these students also appeared to show an acceptance of the relevance of the computers in learning mathematics but only after they had participated in online activities which provided dynamic content and interactivity (refer to section 5.4.5).

In terms of interface design factors it appears from this study that the navigational scaffolding and interactive activities that provide immediate feedback to learners play an important role in students' successful experience in blended online learning. It confirms the view expressed in earlier research of using the web in classrooms that students gloss over information as they explore a website and are likely to miss important information (Clark, Hosticka, Kent, & Browne, 1998) and that students require scaffolding to focus their surfing tendencies (Gerber & Shuell, 1998). The success of navigational scaffolding provided in the design of MCA Online website also supports the view that information on the website should be chunked to prevent overload during processing in working memory (Ally, 2004) and that students are more focussed in using the web in mathematics learning when the teacher is able to do the initial screening for relevant content (Gueudet, 2006). This study shows that careful planning and navigational scaffolding can make the use of the web free of distractions and more focussed on learning mathematics.

6.2.3 Course Design Factors

Students' participation in online learning was also affected by how the course was designed and delivered. During the first cycle of the study I had noticed that students' participation with the online environment remained marginal when online components were not directly linked to classroom learning and assessment. As a conjecture we anticipated that if we presented discipline specific content in an online design that was closely linked to their classroom work, students enrolled in a mathematics module would be able to use it more effectively and benefit from it. However during the enactment stage of the first cycle of this study it became clear that students use the online activities only when they are an integral part of their learning program. We found that students were too occupied with their regular course work and had very little time left for self-directed learning using the online environment.

Recent research from the Australian vocational education sector points to the success of online learning when it is blended with face-to-face classroom learning (Brennan, 2003; Brown, 2003; Fisher, 2003). From a survey of more than 400 vocational education students Cashion and Palmieri (2002) note that hybrid or blended delivery was seen very positively by both teachers and students because it offered "flexibility together with the benefits of both face-to-face teacher supported instruction and online learning" (p.9). In the second cycle of this research when we used a blended learning environment it appears that students' participation in online activities was positively affected as discussed earlier in Section 6.2.1.

But, the nature and volume of course content to be covered during this 30-hour module appears to have had some bearing on participation in online blended learning. The range and scope of learning outcomes prescribed for this module (refer to section 5.2.1) demanded a pace of teaching to which most students seem to have had difficulty adjusting. Although students valued what was covered and agreed that it was relevant for their field of work, in terms of fostering conceptual understanding they thought that the whole module was quite fast paced. Students who were returning to study after a gap of few years complained that they needed more time to cover each topic. One student commented that:

I don't probably need more support, I need more time. With me, it's just an individual thing, I need more time than others that went through the VCE which isn't there. Like this course had brought in mature age but with this maths class they don't supply what we need for it like the time factor....For me that's not there, maybe for other mature age…they could get it if they're mathematically minded, but I'm not, so just probably for me it's not good, not right for me the way it was, like every module gives us only two weeks and it's not enough time for me....It is very much. Look I want to try, that's why I'm attending every class but it's just… [Interview transcript: student - Peter]

When asked about the content of the course and what they felt about its relevance to their future goals students were mostly positive. While some could give specific examples of how topics covered in this course were relevant for their work, others were vague in their response but generally felt that things learned would be needed in future. For example one student recalled the topic of interest calculations and said that:

Yeah it's good, it's relevant and I find it useful b/c we're doing some work about interest and about, I think it was, putting money in the bank and then working out the interest and in a couple of years and so on how much money you will earn, or how much interest you earn. And I was really interested in that, and I wouldn't mind doing that myself, and the procedures in which we went about doing that was helpful. [Interview transcript: student – Paul]

Another student responding to the same question noted that:

We talk about is amongst ourselves, we don't see right now what the role of some of them are but maybe when we're in the job we'll realise why we done it at the time. Like some subjects, within the modules, you know 'why are we doing this' maybe we don't realize it now but maybe later in the future it is going to be helpful to us to know...Yes it's structured really good, there is a lot of hard work when you put it in you'll see the results, but if you don't you'll get snowballed but if you put it in it's really well-structured the course and you're given enough time to do it all. [Interview transcript: student- Peter]

A mature age student who had experience of working in the field noted that:

> *Oh definitely the maths. I was a bit surprised, for a couple of reasons, how much I'd forgotten since high school, I remembered the words but all the little (inaud) and formulas I'd forgotten, but it makes a lot more sense. I remember in the workplace trying to figure out (inaud) and you can see how simple it is and the utilisation of formulas I thought 'this is really applicable to any kind of business'. And I'm still a bit surprised that's it's at such a basic level, it's still a little bit difficult and challenging for me but I figure if you're going to go into business you've got to understand...[comparing it with high school] Definitely. It was a bit more you have to do it and you didn't enjoy it but now, being in the workforce before…it makes a lot more sense. Very relevant.* [Interview transcript: student- Jacob]

In terms of relevance it seems that students were able to make a connection between topics covered in the module and their relevance for workplace and industry. It is possible that Cathy's selection of authentic and industry relevant worded problems for practice exercise sheets helped students make this connection between mathematics processes and workplace relevance. The selection of online activities made this link stronger because students could draw information and use tools available directly from industry sources. In this way presentation of authentic and industry relevant mathematics content seems to have assisted student participation in blended online learning. One student commenting on the relevance of content and the use of computers and the Internet noted that:

> *Most of the stuff I've learnt in this course helps me, in my workplace, I'm learning like computers and Internet… you learn more and when you go outside you pay more attention to them.* [Interview transcript: student – Tina]

Conversely, the pace of teaching and lack of time for consolidation of learning seems to have put students under pressure and left them with little time to engage with exploratory activities available from online environment. For a full time student, the overall load of coursework during a semester seems to be such that it left little time for additional learning activities or participation in discussion board exchanges. During mid semester many students appeared to be stressed with the pressure of tests and assignments from their course. One student responding to a question on factors affecting their study noted that the load of class work and tests was affecting her. She said:

> *Yes, other classwork. Too much. This day I have three tests already…crazy, explode. Too much. Tests is just like you may remember but you don't learn nothing, you forget, assignment then you study, you know.* [Interview transcript: student - Kate]

In addition, Cathy reported in week eight that two teachers from her department had been given teaching assignments in China and because they will leave in two weeks time they had given students assessment tasks early to finalise results before leaving for China. This extra load on students seems to have had a flow on effect and their participation in mathematics module in terms of attendance and participation in learning activities. The pace of teaching and load of subjects being studied during a semester seems to have negatively impacted on participation of students in blended online learning as they could not afford additional time required for engagement with online activities beyond classroom contact hours.

Our observations regarding the course design factors confirm previous research that in the vocational education field conventional courses and delivery strategies limit their suitability for online learning environments and an improvement in learning materials and assessment strategies is needed to see better use of online technologies in developing more effective learning environments (Oliver, 2004). The nature and volume of content load on students seemed to affect their ability to participate in flexible learning opportunities offered by an online learning environment. However, blending face-to-face learning with online activities in the classroom affected students' participation positively although some students used the online environment to a limited extent only.

6.3 Access and Use of Online Environment

In this section of the chapter analysis and interpretation of qualitative and quantitative data related to how students access and use the online environment for their learning needs is presented. This part of research aimed to identify patterns of access and use in relation to home and school access to Internet, preferred online activities, access to and use of online communication tools in learning mathematics and the role of computer and mathematical skills in the use of mathematics related online content.

Two design conjectures were linked to the research question on how students access and use the blended online environment for learning mathematics: one related to the flexibility provided by online environment and noted that blended learning would lead to improved retention of students in the course because those students who are unable to attend particular face-to-face sessions would be able to continue with the module and participate in learning activities by accessing the course website from home. The second conjecture related to enhanced communication opportunities provided by the online medium and noted that continual and extended use of discussion board communication would lead to the development of a community of practice that is able to solve problems using this new medium of communication to share knowledge and information. In the following section I will draw on classroom observations, WebCT data, student journals and interview transcripts to identify and report patterns of students' access to and use of online learning environment.

6.3.1 Access to Internet

Because mathematics lessons during the second cycle of this study were conducted in a multipurpose classroom where computer access was readily available, access to the online environment from classroom was not a problem. Students were also able to access the Internet from networked computers in the library and open access computer labs and in this way access to the Internet from campus was freely available.

In a questionnaire administered to the treatment group students (Appendix 17) four out of 24 students reported that they had no access to the Internet from home. Journal entries by students during three sessions indicated that most students accessed the Internet from both home and school. Popular locations for accessing the Internet as calculated by counting the number of occurrences of words (home, school, work and library) in students' journal entries reveals that school and home account for more than 90% of access locations for the Internet, and home was used more often (48%) than school (43%) for accessing the Internet by students (Figure 6.3). Despite home and school appearing to be equally preferred locations for accessing the Internet from journal entries, records from course website access count and WebCT discussion board postings reveal that students accessed the online learning environment mainly from the classroom with 77% of the postings on the discussion board made during school hours (Figure 6.7).

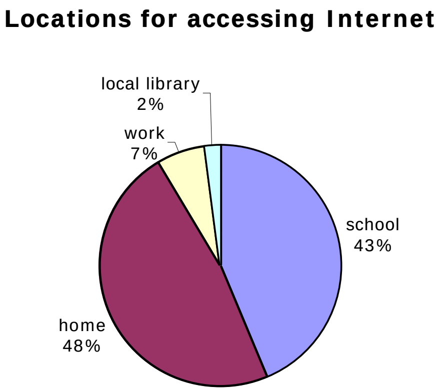

Figure 6.3. Distribution of locations for accessing the Internet as indicated by students' journal entries.

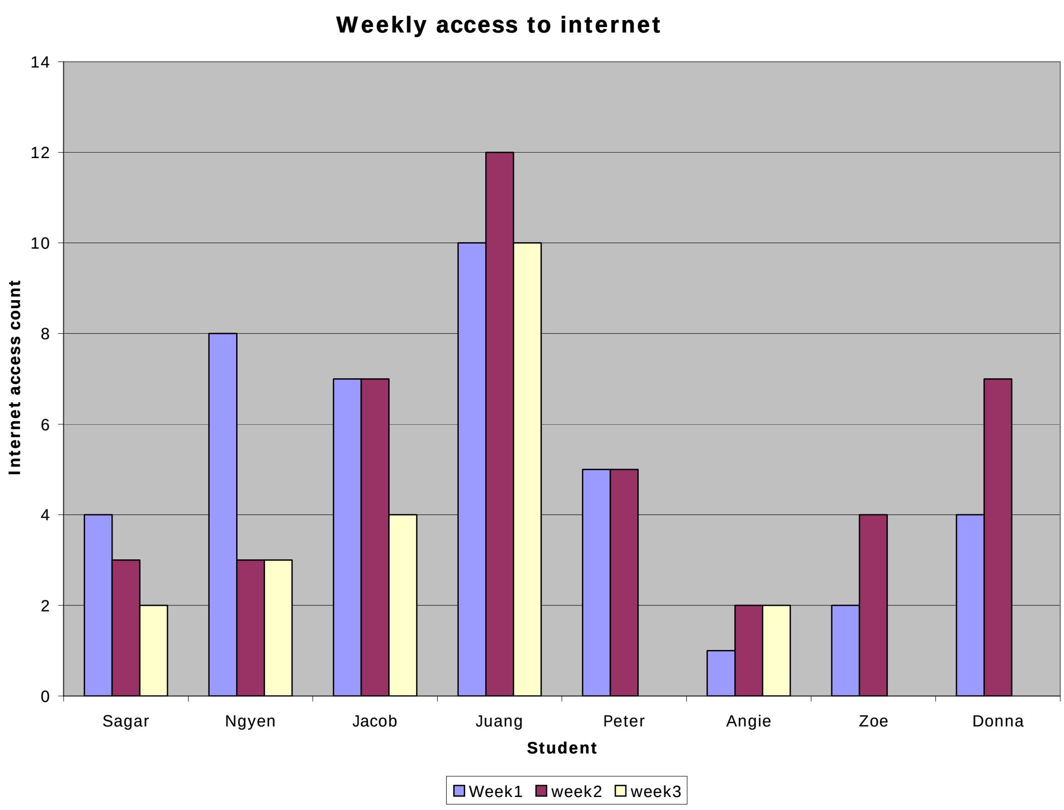

Figure 6.4. Weekly count of access to Internet as reported by students.

It became clear from the data obtained from student questionnaire and three weekly journals completed by students that access to Internet was readily available to most of the students and school and home were the main locations from where they accessed the Internet. However, as WebCT data and access to the course home page suggests, this ready accessibility of Internet did not lead students to access and use the online environment from outside the campus locations as expected in our conjecture at the start of this cycle of the study.

In response to the question in the journal template about how many times a student went on the Internet during last seven days only five students completed the journal entry for all three weeks and two amongst them (Juang and Jacob) reported accessing the Internet between 4 and 12 times in a week. Other students reported accessing the Internet between one and eight times per week (See Figure 6.4).

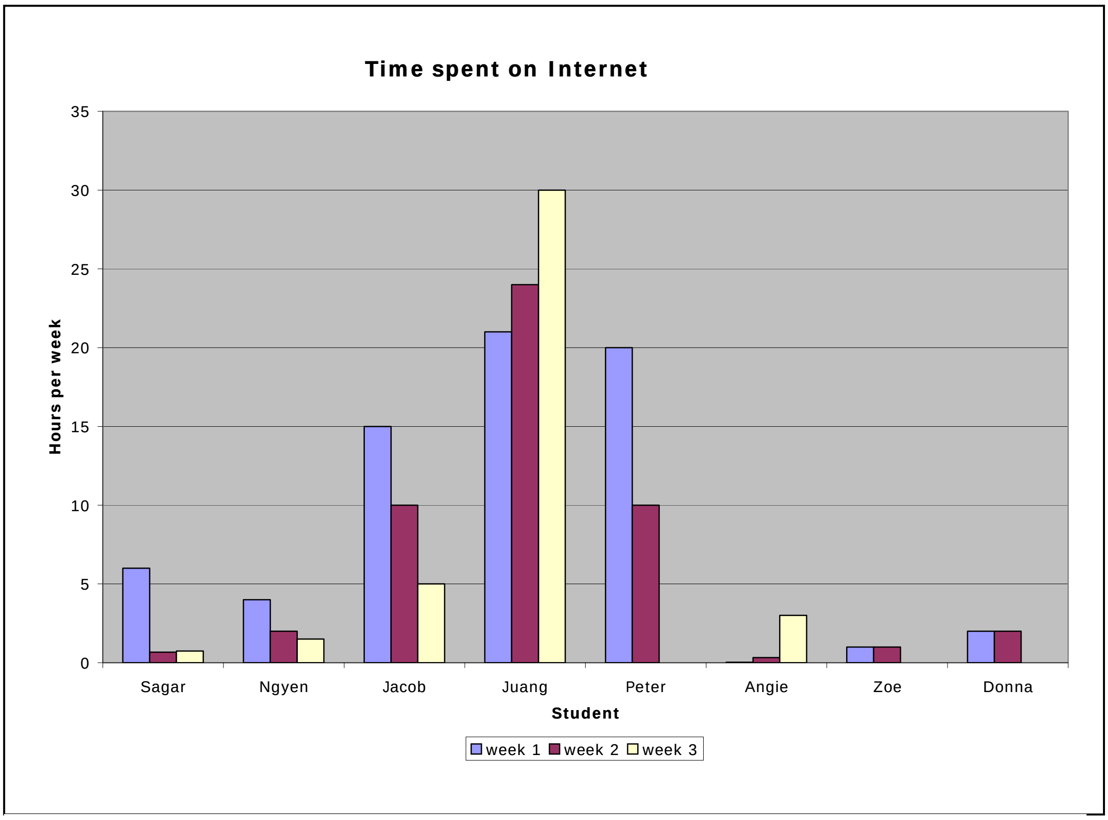

Figure 6.5. Number of hours spent on Internet as reported by students.

Juang and Jacob also appear to have been more confident users of the Internet and in response to the question about how much time they spent on the Internet during the week these two students and another student, Peter, reported using the Internet in the range of five to 30 hours during the week (Figure 6.5). Another five students filling in journal entries reported using the Internet between less than an hour and five hours per week. Some entries in the journal listed Internet use only for a few minutes and it appears that some students misread the question and reported only daily use rather than hours used for the week. At least one student confirmed this in a follow up session and her record was corrected. It is also worth noting that because of irregular attendance pattern many students missed the opportunity to complete weekly journals.

In journal entries students reported that the main activities on the Internet were mostly related to the course including research for assignments. For an open-ended question asking students to list and describe their main activities on the Internet a wide range of responses were received. These responses were grouped into five main categories: *school work; games; chat; email* and *personal research*. The *school work* category included terms like assignments, exams, school subjects, homework and research. The category listed as *personal research* included activities such as banking, exchange rate, news, weather, music and job search.

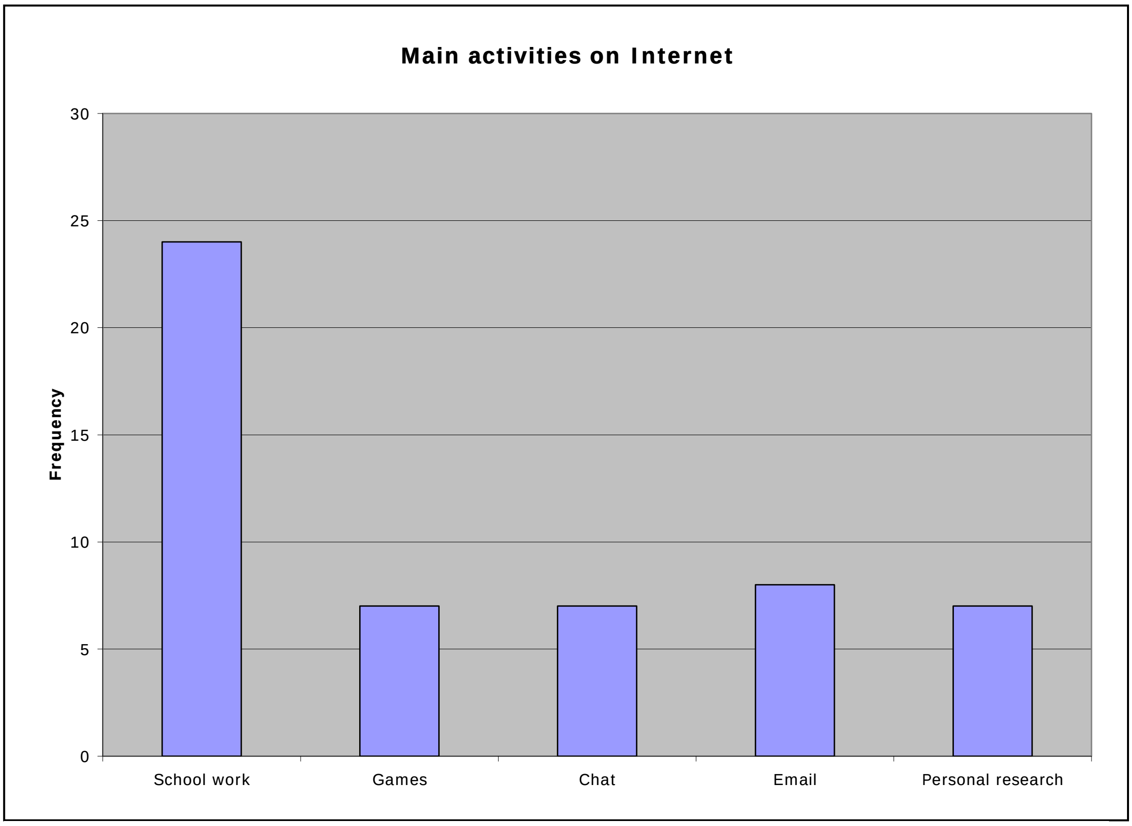

Figure 6.6. Students' main activities on the Internet

Figure 6.6 shows the frequency of responses under each category where activities described as email, chat, games and personal research are ranked closely in terms of their use by students. Schoolwork is reported as the most frequent reason for students' access to Internet.

The journal entries helped in identifying students who were more active online users and it was expected that these students would have no difficulty in accessing and using the mathematics online learning environment designed for this module. When WebCT logs were analysed for students' access and postings it was found that the majority of postings and follow up comments on the discussion board were posted during school hours with more than 75% of postings occurring between 11 am and 5 pm. In fact 71% of postings happened between the hours of 11 am and 2 pm showing that classroom contact hours (11am to 1pm) were responsible for most of the activity in the online environment. There were a very small number of active online students who posted messages and accessed the WebCT home page after school hours. As shown by the distribution of postings on WebCT in Figure 6.7, nineteen per cent of postings were recorded during evening and late night hours.

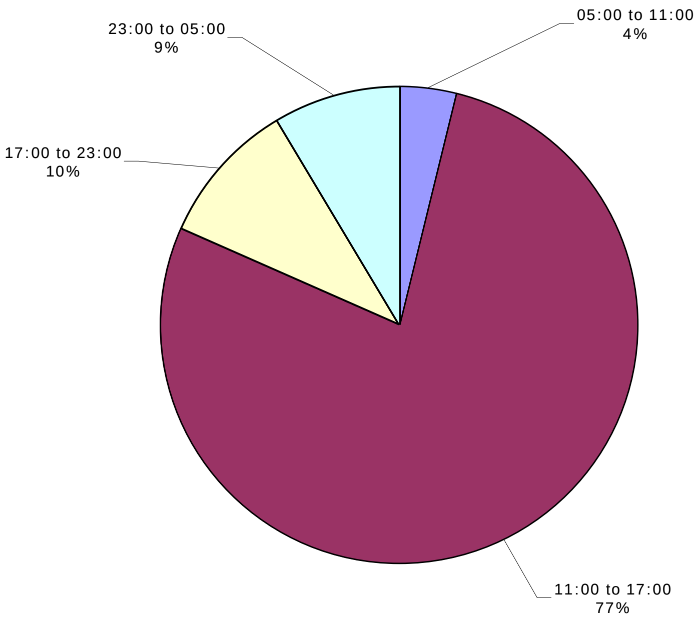

Figure 6.7. Distribution of WebCT postings according to time they were posted.

The blended learning format allowed students time to use the online environment during class hours and it is not surprising that most of the access occurred during school hours. Research has consistently shown that blended learning is preferred by VET trainers, teachers and learners, and most persistent and successful use of new technologies takes place in blended learning where face-to-face teaching is mixed with online learning (Brennan, 2003; Cashion & Palmieri, 2002; Josie Misko, Choi, Hong, & Lee, 2004; Stehlik, Simons, Kerkham, Pearce, & Gronold, 2003). The findings from this study are thus consistent with previous research.

6.3.2 Use of Online Communication

After the limited success of online chat facility in the MCA Online website during the first research cycle, the design for the WebCT module included only email and discussion board communication facilities. Smith and Ferguson (2005) note particular difficulties of communicating mathematics in an online chat and discussion forum but the potential of student – student and student – teacher interaction in an online discussion format led Cathy and me to design learning activities where students were expected to take part in the online discussion board by posting messages and responding to other messages.

Bransford, Brown and Cocking (1999) point out the communication afforded by new technologies can assist in mathematics learning by making it easier for teachers to give students feedback and connect classroom to community at both local and global levels. This view was also supported by Kaput and Thompson (1994) who predicted that the “connectivity” aspect of new technologies which allows them to link teachers to teachers, students to students and student to teacher are a source of power to change the “experience of doing, learning and even teaching mathematics” (p. 679). The message board and email facilities built into the WebCT home page and links to the Ask Dr. Math archive (Drexel University, 2000) from the resource page were aiming to introduce students to this new experience of doing and learning mathematics.

In terms of students using WebCT discussion board to post messages and exchange ideas in an asynchronous mode, analysis of WebCT logs shows limited use made by students. WebCT logs show that the access and use of the discussion board by students varied on an individual level with an average of 2.3 for original postings and an average of 1.7 for follow up postings. Students who had reported access and regular use of Internet in weekly journal entries showed above average use of discussion board but there was no clear pattern as many students who dropped out of the course after a few weeks also registered above average discussion board usage (Figure 6.8).

It appears that most students used the discussion board only when it was part of an online activity where the teacher had provided clear instructions for posting students responses on the discussion board (for example the algebra online activity for posting worded problems based on linear equations, refer to Chapter 5, Section 5.4.2). There was little evidence of postings where students had initiated a posting to seek assistance from other students or the teacher.

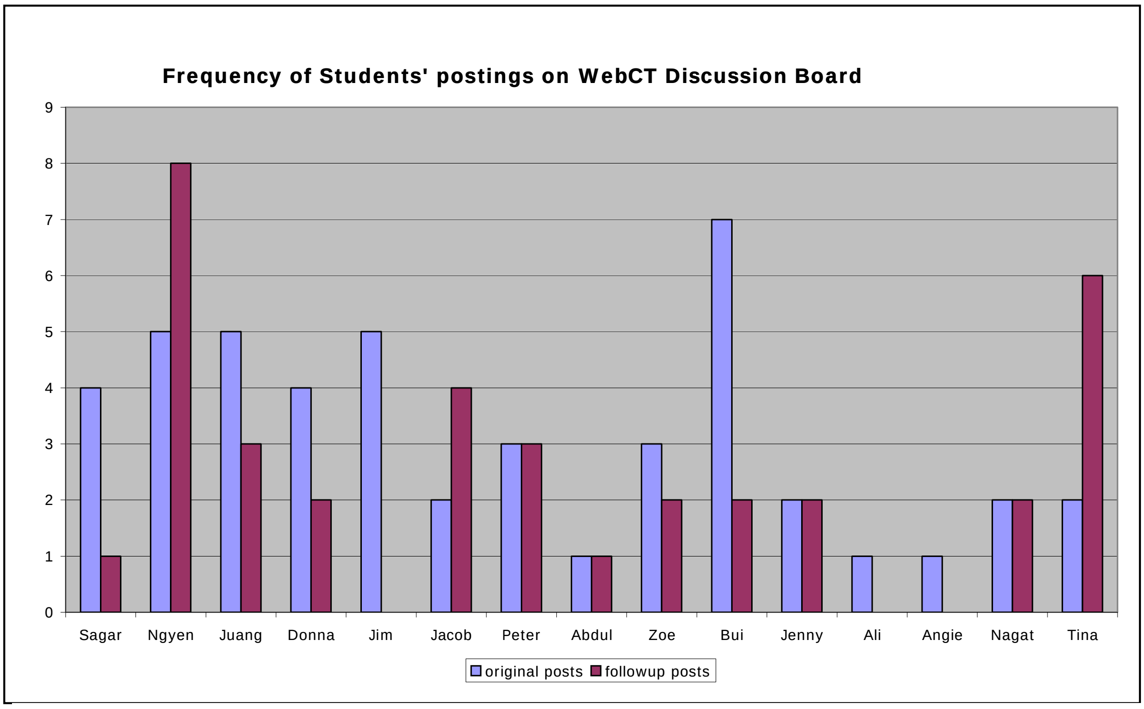

Figure 6.8. Frequency of postings by students on the WebCT discussion board.

Figure 6.9 clearly illustrates that students' postings were significantly higher for the topics where online activity required students to post responses to the discussion board. Both Algebra and Depreciation topics required students to post messages on the WebCT discussion board and Table 6.5 shows that these two topics had the highest numbers of postings recorded. The Depreciation online activity included an online assessment task where students were asked to submit their work via online posting but the algebra online activity was a genuine collaborative activity where students had to create a word problem and post it on the discussion board for other students to solve. Although it was a non-assessment task students took a keen interest in it and a flurry of postings appeared during the session. However, when other topics such as Percentages, Interest and Linear Equations left the posting of responses on the discussion board as an optional activity WebCT logs showed significantly less activity.

Although data from students' weekly journals and WebCT logs show that students reported frequent use of the Internet in their journal entries and taking part in WebCT postings regularly, there is little evidence to suggest that students used the discussion board to generate social communication. The only messages appearing to show some informal social interaction were the messages posted during introductions in the first session. It appears that the tone of mathematics lessons set in class created an expectation of problem solving and calculations-based view of mathematics and use of discussion board for generating social contact was not necessary when the class was able to interact in a face-to-face classroom.

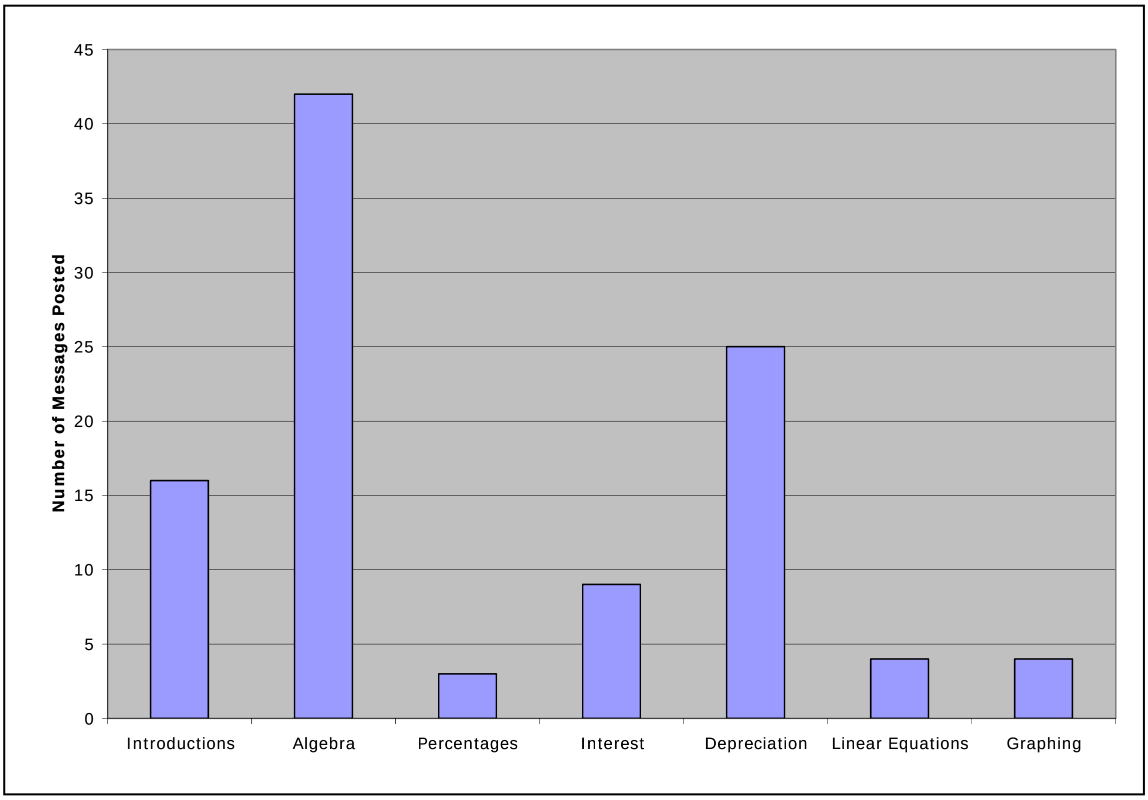

Figure 6.9. Messages posted on the discussion board during different topics.

The teacher's contribution in promoting and encouraging the use of the discussion board by students also appears to be very limited and it is clear from Table 6.6 that most of the teacher's postings were related to posting online tasks and there were only two prompts for responses. It appears that the nature of online activities and topics being covered did not create a need for students to engage in collaborative online communication via the discussion board except for the topic of algebra online activity. This analysis shows that the online medium requires teachers to be more creative in their design of activities and the teaching of conventional mathematics with the help of online collaborative communication is a challenging task.

Table 6.5
Postings by students

Posting Type	Number of Students who Posted Messages	Number of Messages Posted
Introduction message	13	16
Algebra online activity	12	22
Reply to student posts	9	19
Interest online activity	6	9
Depreciation online activity	6	13
Depreciation assessment task	9	9

Table 6.6
Postings by teacher

Posting Type	Number of Postings	Receiver
Online Tasks	6	Group
Prompts for response	2	Group
Reminders	4	Group
Posting Results	3	Individual

6.3.3 Computer Skills and Use of Online environment for Mathematics

Observations of the treatment group class revealed that although confident users of computers were able to access and navigate the online learning environment with relative ease, their confidence in using computers did not necessarily turn them into effective and productive users of mathematics in the online environment. The ASCII symbols used in mathematical online tools and content knowledge assumptions implicit in external mathematics and financial websites posed problems for students and they had to learn and work out how to use the tools and resources from these sites. Direct links to relevant tools and resources saved students from being distracted or lost in navigation but Cathy and I had to provide direct assistance in explaining symbols and jargon commonly used on external websites.

Some students were more active users of the online medium and used to log onto computers and access their email and chat programs while the class was doing face-to-face teaching. They appeared to be quite at ease with skills required in accessing email, chatting and browsing popular media websites and when it came to using WebCT, online tools for mathematical tasks and navigating a website like Ask Dr Math, they quickly became familiar with the new learning medium. Although working with mathematics in an online medium required new learning such as understanding ASCII symbols for mathematical operations they needed less assistance and once they had learned these new skills they were willing to help other students in class who were slow to pick up new skills and had less confidence in working with computers.

It appears that the students' meta-cognition skills played an important role in determining the extent and quality of their use of the online learning environment. These meta-cognition skills involved their ability to plan and decide their goals and what strategies are best to get there, their ability to monitor and evaluate their progress and their ability to decide when to terminate a particular course of activity (Biggs & Moore, 1993). In order to develop an understanding of how meta-cognitive skills played a role in student participation and use of the blended learning environment six detailed cases of students from the treatment group were written up. For the purpose of illustrating students' selective use of the online learning environment I have presented a brief account of two cases where students approached the online activities differently based on their computer and meta-cognition skills.

6.3.3.1 Case 1: Juang

Juang was a 19-year-old male student whose parents came from Philippines. He had completed his year 12 the previous year and had studied mathematics methods (the mathematics subject that is normally required for entry into tertiary mathematics and science courses) and further mathematics as part of his VCE subjects. Juang was a cheerful young person who enjoyed being at school. He attended all sessions for the mathematics module and liked participating in class activities. He appeared confident in mathematics and showed a positive attitude towards it with a pre-test score of +6 on the attitude scale. He was doing this course because he liked to work in the import-export industry and liked to travel overseas. He saw mathematics as an area of study with close relevance to life. In the interview session he remarked that "from my view maths is needed everywhere… (I) got no problem with maths at all". Juang worked well in this module and participated in both print based and online activities. His attitude towards mathematics improved considerably during this course and his post-test attitude score increased to +18.

Juang appeared to be a confident user of computers and had a computer at home. He also had access to the Internet from home and used it for research, chatting, email, news and other interests. In his three weekly journal entries he reported using the Internet on average for two to three hours per day from home. In comparison to other members of his class Juang reported the most prolific use of the Internet from home but this familiarity, ease of access and competence in working on the Internet did not result in greater access and use of the online learning environment in mathematics. Juang's access count on WebCT showed a modest access count of 51 and articles read count of 26. However, it appears that Juang made good use of his chatting and online communication skills by posting 5 original and 3 follow-up messages. Class observation and WebCT logs of Juang's participation in online activities shows that although he did not access the online learning environment as frequently as some other members of his class, his use was highly selective and aimed at meeting the requirements set by the teacher.

During online activities on the topic of algebra when students were asked to write a worded problem that can be solved by using a simple algebra equation he posted the following problem:

> *Tony worked at Malvern Post office. He works 25 hours on weekdays on a normal average rate of $14.57 per hour and works 5 hours on Saturdays which*

is a rate of one and a half of normal rate. Tony also took some stamps home valued at $9 which will be deducted from his pay.
How much wages in (sic) Tony going to get this week?
All the best of luck to everyone solving the problem.
Another Juang production!

The difficulties in communicating mathematics in the online discussion were clearly visible from students' attempts at writing mathematical expressions in their postings. The following example of Juang's attempt at posting a solution of an equation on the discussion board is a clear example:

x(x+1) = 8556; xSquared + x = 8556; xSquared + 1x – 8556 = 0
(x + 93) (x – 92) = 0

His confidence with computer use and access to the Internet from home appears to have made a meaningful contribution towards his learning as he acknowledged that:

…I live far away from here, it's good when you come home and you don't know what's happening, you can have a look you open it up, see what homework you have, you do it on the web, it's as easy as that. Seeing all the handouts, it's all too, it's difficult, you've got a lot of work to see which one's this, but I think through the Internet's much better. Good anytime.

Juang attended all sessions for the module and successfully passed five out of six weekly tests. His final test score was 75% showing that Juang was able to perform well in this module. The case of Juang shows that he was a confident student with good computer and meta-cognition skills. He had learned mathematics at school and this preparation seems to have helped him to cope with the demands of this module well. He liked the Internet based learning and used it selectively to suit his learning goals.

6.3.3.2 Case 2: Peter

Peter was a 33-year-old mature age student from a Yugoslavian background who joined this course after working for 15 years in a national freight company. He wanted to broaden his skills and knowledge to be able to work in an international trade context. After finishing year 10 he had left school and joined the workforce. He appeared sincere and motivated in his learning but there were clear signs of mathematics anxiety. His attendance during the semester was 83% and he completed all assessment tasks and took part in the final test for the module. He had another mature age friend doing this course with him and both worked well together.

Peter showed a pronounced negative attitude towards mathematics with a pre-test score of –20 on mathematics attitude scale. In his interview he expressed his fear of mathematics in very clear terms. He pointed out that he could not remember that he had done these things in maths ever before and he was shocked to see that he was so poor in his mathematics skills. A reason for his mathematics anxiety seemed to emerge from his understanding that he had very little mathematics background. He pointed out that:

> *I only completed year 10 when I left school 15 years ago, cos I'm a mature age now, I'm 33, I've been working the last ten years in trades. I've never needed mathematics in my old job where I was before, mathematics wasn't something I needed to do in the last 10 years so it doesn't come easy for me to do.*

Peter had experience of using computers and had his own computer at home. He also had a connection to the Internet from home. As indicated by entries in his weekly journals Peter was a frequent user of the Internet from home with 10 to 20 hours of Internet use in a week. He used to go on the Internet for entertainment but since joining this course had started spending most of his time on course related research and assignments. It appears that he liked the online learning environment for mathematics as he had the second highest access count for WebCT home page and had fourth highest count for articles read. He posted six messages on the discussion board with five messages related directly to work requirements for online tasks and one was posted as a response to another student's answer to a mathematics problem.

Peter's main issue with the course was the fast pace at which it moved and did not give him opportunities to learn at his own pace. For him the requirements of the course were too much and too rushed. When asked about what were the bad points about this course from his point of view he pointed out:

I don't probably need more support, I need more time. With me, it's just an individual thing, I need more time than others that went through the VCE which isn't there (which I don't have). Like this course had brought in (taken in) mature age but with this maths class they don't supply what we need for it like the time factor... For me that's not there, maybe for other mature age… they could get it if they're mathematically minded, but I'm not, so just probably for me it's not good, not right for me the way it was, like every module (topic) gives us only two weeks and it's not enough time for me... It is very much. Look I want to try, that's why I'm attending every class but it's just…

But he liked the idea of assignments and assessment being accessible in an online environment that included flexibility so he could do things at his pace and beyond the time frame of the classroom. When asked about whether he thought computers and the online environment made learning easier, he gave an example of how it helped his learning. He remarked:

Definitely...When we done that assignment at home, depreciation or something, that gave me a lot of time to at first understand it, I went on my own pace, I wasn't limited in two hours class to do it, and if I was stuck on something I would go away from it and come back and solve the problem that way, but if I was stuck in class...yeah I'm under time pressure, so it was good to do that assignment at home and I was confident that I would complete it. Whereas here if I was in class for two hours can I complete this, if not…

Peter failed his three weekly assessment tasks on the topics of algebra, interest and linear graphing but passed his final test with a 50% score. His performance in class activities was poor during first half of the course and his mathematics anxiety remained till the end. His post-test attitude score on mathematics attitude remained –20.

This case shows the difficulties Peter faced in learning and meeting the requirements of the mathematics module as a mature age student who had enrolled in this diploma course after a gap of 15 years from school. It also shows that the online learning environment offered help and assistance to support his learning but the nature of assessment tasks and pace of teaching were too much of a burden for his learning capabilities. It appears that being a confident user of the Internet helped him participate in the online environment with confidence but due to poor time management skills and a lack of confidence in mathematics he was unable to be selective in his use of the online learning environment. He managed to complete his diploma course successfully in the following year.

6.3.4 Using Meta-cognition

These two cases illustrate the important role of students' confidence and meta-cognition skills for making effective use of the online learning environment. While Juang appeared to be well prepared for the course and used his meta-cognition skills and confidence to selectively use learning resources from the face-to-face and online environments to meet the requirements of learning activities and assessment tasks, Peter came to this course after a gap of many years and did not seem to be prepared to cope with the pace of learning expected in this course. Peter appeared to use the online learning environment more but lacked the meta-cognition skills of a confident student to apply it to course demands.

In addition, the difference in prior knowledge of mathematics that these two students brought to this course also seems to have affected their confidence and use of the online learning environment. While Juang, having done mathematics subjects in his VCE studies, was more confident and used the online environment to his advantage, Peter, on the other hand, came with limited prior knowledge of mathematics having completed only a year 10 mathematics course several years ago. He lacked confidence and it appears that his above average access and use of the online environment is an indication of his desire to overcome his anxiety in mathematics. Research with adult learners has shown that anxiety and low confidence affects learners' performance in mathematics (Coben, 2003; FitzSimons, 2002a). Although Peter appears to have made reasonable efforts both in the face-to-face sessions and in online activities, the pace of learning in the course did not allow him to catch up on mathematical concepts he needed to learn and master.

In relation to students' computer skills and their use of the online learning environment to learn mathematics this study supports previous research by Cretchley and Galbraith (2003) that students' computer confidence and motivation levels do not show a strong association with their mathematics confidence and motivation. This study confirms that in a vocational education mathematics course also students who show high confidence and motivation with computers do not necessarily show a similar attitude in their mathematics learning. This study indicates that students with a positive attitude and motivation towards mathematics were more likely to adapt their meta-cognitive skills of planning, monitoring and evaluating their progress in using the blended learning environment and achieving their goal of passing the assessment tasks. For example, they posted messages on the discussion board only when it was required and did not spend their time on online activities when they were not an essential part of assessment tasks. These findings have implications for teachers and course designers in vocational education where many students may come to a mathematics course with good computer skills but a negative attitude and low confidence in mathematics. In order to harness students' interest and skills in computers towards mathematics learning we may need to modify our thinking about course design factors such as the nature and amount of content expected to be covered in a module, pace of teaching and explicit attention to teaching meta-cognitive skills for learning with computers.

6.4 Teacher's Role in Blended Learning

This section of the chapter concerning analysis and interpretation of practice is aimed at responding to the research question: How does integrating an online environment in classroom-based learning of mathematics affect a teacher's role?

The significant role played by the teacher in online learning has been documented by research in the vocational education and training sector (Brennan, 2003; Cashion & Palmieri, 2002; Stehlik, Simons, Kerkham, Pearce, & Gronold, 2003). Studies have also shown that an entirely online mode of learning is less common in this sector and most students and teachers prefer to learn in a blended online format where online learning is mixed with some form of face-to-face teaching (Cashion & Palmieri, 2003; Simons & Stehlik, 2004). Cashion and Palmieri (2002) in their research report titled, 'The secret is the teacher' note that, "Quality online learning relies on the work of good teachers. Responsive, helpful, knowledgeable teachers facilitate an effective online learning experience" (p. 9). In a mathematics classroom where a teacher is attempting to integrate online technologies with traditional face-to-face learning the issues of the teacher's technical skills, access to resources, organizational and structural support and their own instructional beliefs play an important role in effective design and implementation of technology supported learning (Ertmer, Addison, Lane, Ross, & Woods, 1999; Forgasz, 2006b; Handal, 2004). In order to analyze blended online learning from a classroom teachers' perspective and how it affects the role of the teacher I will use the framework first proposed by Berge (1995) and applied by Bonk, Kirkley, Hara and Dennon (2001) in describing and analyzing the teacher's role in post secondary online learning. This framework expresses the teacher's role in terms of pedagogical, social, managerial and technical actions and identifies practices that are likely to assist in the success of online learning including blended online learning. In addition, while discussing the teacher's technical role in a technology rich learning environment I would also draw on the framework adapted by Goos (2006) to analyze the interactions that occur between the teacher and the learning environment.

In my analysis Berge's framework is conceptualized as representing a teacher's pedagogical practice in the context of different roles. It is also important to acknowledge that these roles played by the teacher are fundamentally influenced by their pedagogical, mathematical and epistemological beliefs (Handal, 2004). The pedagogical role of the teacher covers everything concerned with teaching and facilitating education processes for students to develop understanding of key concepts, ideas, and skills. The managerial role involves dealing with organizational, administrative and procedural tasks and issues concerned with teaching in an online supported environment (Berge, 1995). The social role aims at promoting a friendly environment and a sense of community amongst learners. It includes actions like attending to learners' individual concerns, providing feedback and reward and encouraging participation. The technical role involves dealing with technical issues related to course design and implementation, referring students to appropriate support resources, diagnosing and clarifying problems encountered by students and assisting students in learning new online tools and applications (Bonk, Kirkley, Hara, & Dennen, 2001; Teles, Ashton, Roberts, & Tzoneva, 2001). Although Berge's framework categorizes teachers' role in four distinct functions, these roles need not be perceived as compartmentalized and in this study the role specified as technical is also perceived as pedagogical.

Cathy played a lead role in the planning and teaching of this mathematics module in a blended learning format. Her interest and involvement in the current study has been documented in detail in chapter 5.1.3. As a teacher/researcher involved in this study, I worked closely with Cathy and in this section I will draw on the framework presented in this section to describe how she managed the pedagogical, managerial, social and technical roles in the context of a blended learning environment in teaching a mathematics module.

6.4.1 Pedagogical Role

A teacher's own understanding about mathematical knowledge, mathematics teaching and mathematics directly influences their decisions about what to teach and how to teach it (Ball, 2000; Bransford, Brown, & Cocking, 1999). Cathy was an experienced teacher who had worked in secondary schools before moving to the vocational education sector. She also had extensive experience of teaching mathematics in the business and marketing area of the VET sector. She had interest in online technologies and was a steering group member of the MCA Online project during the first cycle of this study. Working within the constraints imposed by the modularised and competency based assessment (FitzSimons, 2002a), Cathy had developed her own teaching materials (class notes and exercises) for students. She also knew from previous years' experiences that most students would not buy the recommended mathematics textbook for the module and would rely predominantly on the teacher provided exercises and notes. Her teaching followed a teacher led instruction method that appeared to be closely aligned to the pedagogy of cognitive apprenticeship (Brown, Collins, & Duguid, 1989). She introduced, explained and modelled mathematical concepts and procedures with examples drawn from everyday applications of mathematical concepts in business and marketing. In the traditional teaching method applied with the control group class she would follow up her modelling and direct instruction session with problem exercise sheets where students would work individually and sometimes in pairs to practice the application of the concept and skills learned. She was well at ease with this method and noted that, “… having been teaching maths for quite a number of years I can just walk into class and I can just put up, have a lot examples and all that in traditional mode.”

The use of online learning environment in a blended learning format affected Cathy’s pedagogical role and offered opportunities for additional authentic and interactive learning activities in the class. These interactive learning activities were web-based and offered instant feedback, multiple representations and networking opportunities (Goos, Stillman, & Vale, 2007). Her openness to try new ideas, her involvement in the research project and her willingness to integrate online technologies in the classroom practice suggested openness to new ideas in her teaching approach. Her remark during an interview session that “the curriculum is set and I have to follow it whether I agree or not” hints towards her frustration with limitations imposed by the curriculum.

Although Cathy appeared to accept the prevailing VET model of teaching she appeared also keen to embark upon new approaches. The issue of teaching directed to learning outcomes and competency assessment continued to create a tension regarding choice of learning activities to be used in the class (Ainley, Pratt, & Hansen, 2006). She noted that:

> *…they [students] have got to be competent in every learning outcome and it doesn’t seem to be a holistic approach to things, and I hope that the training package that’s coming out will give us the opportunity to develop training packages [modules] without the limitations of the curriculum because that determines what I put and don’t put in the activities.*

The design and teaching strategies used with the treatment group class show that Cathy’s instructional beliefs were more flexible than expected from a traditional positivist teacher following transmission mode teaching. The online learning medium offered opportunities for interactive, authentic and collaborative learning experiences that Cathy readily incorporated in her teaching sessions. The interactive learning experiences included web-based activities that allowed learners to engage with web-based applications where they were able to input their own data and receive immediate feedback. The authentic learning experiences involved using real data from commercial and public websites in solving problems. In this way the online activities allowed her to extend her traditional face-to-face teaching methods to include elements of constructivist learning (Jonassen, Peck, & Wilson, 1999). For example in a collaborative online activity on the topic of algebra she asked students to create and share a simple word problem from everyday experience (see Chapter 5, Section 5.4.2). In this example she was eliciting students' responses to assess their current understanding of the algebraic concept of equation. Cathy encouraged students to take risks and suggested that they can work in small groups and teams to attempt this problem. In another interactive online activity she asked students to search and evaluate depreciation calculators (see Chapter 5, Section 5.4.5). In this activity she encouraged students to use both manual and calculator based methods to check and verify their own methods and calculator's functionality. As an example of an authentic learning experience Cathy used an online home loan calculator from a Bank's website in an activity where students were exploring the concept of compound interest and how different variable affect the period of loan and the amount of interest paid (see Chapter 5, Section 5.4.3). The approach adopted in these activities is an illustration of how Cathy was able to include elements of constructivist pedagogy in her predominantly teacher-directed instruction.

Clarke (2005) asserts that a common interpretation of the constructivist manifesto has led to de-legitimising of the act of "telling" in a mathematics class (p. 12). He points out that "telling" often labelled as a transmissive teaching approach could play a valid role in teaching if the function played by telling is to introduce new ideas or allow the student to generate knowledge. One clear influence of the online blended format on Cathy's pedagogical role appears to be that her "telling" sessions on particular topics were extended to allow students to explore these concepts further and generate new understanding. For example Cathy used a "telling" approach to teach the transposition method for solving algebraic equations involving interest rate formula P = IRT as this teacher directed approach was considered necessary for teaching them the skill for solving algebraic equations and introducing the concept of simple and compound interest in subsequent lessons. In the following online session students were able to explore the relationship between interest paid on a home loan, interest rate, period of loan and effect of extra repayments through an online calculator which provided simulation for various scenarios. In this way Cathy used the "telling" approach to teach the skills for algebraic transposition but followed it up with online activities that allowed further exploration of the idea to extend students' understanding of the concept on interest amount calculations on a home loan.

Hagan (2005) in her auto-ethnography of teaching mathematics in Melbourne's secondary schools notes that the school culture and expectations and the role of assessment play a key role in dictating a certain style and approach to teaching. This idea is amply demonstrated in the vocational education sector where competency-based training is believed to have led to a largely transmission model for teaching of mathematics (FitzSimons, 2002a). However, it appears that access to the online learning environment and Cathy's pragmatic approach to teaching allowed her to extend a seemingly transmission model of teaching to include more interactive, authentic and collaborative problem solving learning activities in her mathematics teaching. At this point it is also important to recognise that Cathy was well supported in her attempt to integrate online learning with face-to-face teaching by the researcher who took part in the design of the online learning activities as a co-designer for the online learning environment.

6.4.2 Social Role

The social function played by the teacher in an online teaching and learning context relates to the aspects of learning that aims at making the learning environment friendly and supportive and leads to a sense of community among participating learners (Bonk, Kirkley, Hara, & Dennen, 2001). In the traditional classroom teaching of mathematics Cathy's social role remained confined to classroom interactions with students, attending to their learning and assessment needs in a face-to-face situation. She had a pleasing personality and students were able to develop a good rapport with her during the course. She gave her email address to all students in both control and treatment groups and offered them course related assistance. Cathy's offer was taken up by students as one student from the control group class reported in interview:

> *…sometimes I do email the teacher and find out information from her, I ask the classmates if I miss out class. I emailed Cathy before cos I missed a class which I got a test that week, so I emailed her to make a time for me. She replied*

> *straight away. Yeah, cos that time I was in a computer class and she emailed me so fast, it's easier.* [Interview transcript: student- Kate]

Cathy was always willing to assist students and also helped them outside class hours. But, as she reported in interview other factors such as timetabling and whether students had another class just after their mathematics class made a big difference. She reported, "One of the groups that [was] not an online group actually approached me more but that's possibly because of their time-table". In fact this class had a free period after their mathematics class. Although Cathy had offered her email address to all students doing mathematics, she reported that the treatment group class contacted her by email the most. In response to the question that whether she noticed any difference between control and treatment groups in terms of email contact, she reported:

> *Yes, actually this particular group [treatment group] have thought of using email more than the others so it has made a difference even though it wasn't of maths homepage [WebCT], they tried to communicate electronically anyway.*

Cathy's social role with the treatment group class included an additional dimension in the online environment. Apart from face-to-face interaction with students she also had to play a lead role in the online environment. Research has shown that the online social role requires instructors to develop nurturing skills because learners need to be encouraged to participate in online environments by means of ample feedback and reward (Laurillard, 1997; Manor, 2003). In this study the discussion board component of the online environment required the teacher to play a significant social role. It was this communication medium that allowed the teacher to post weekly online activities for students and encouraged their participation in postings. For both Cathy and the students of the treatment group class the use of online discussion board was a new experience. Having a look at the number of messages posted by students on different topics and the number of messages posted by the teacher for various tasks as shown in Table 6.5 it appears that limited use was made of the discussion board. Cathy posted a total of 15 messages on the discussion board and six of these were online activity tasks for topics covered during the semester (Table 6.6).

Research has found that discussion board activities are less readily accepted in mathematics learning. Schuck (2003) in a study with first year teacher education students reported that almost 60% of students did not visit the online forum used as part of their mathematics education subject. Smith and Ferguson (2005) in their study of attrition rates in undergraduate mathematics courses offered in online distance education mode in the U.S. A. note that threaded discussions work well where students read and discuss papers but threaded discussions are not very useful for mathematics courses where problem solving is more important than discussion. In our module, Cathy used the discussion board largely as a communication medium to keep students informed about their class work. Out of the six online tasks posted by her only one was an open-ended task on the topic of algebra where students had an opportunity to use the discussion board in a creative way (see Chapter 5, Section 5.4.2). The remaining online tasks were mainly concerned with practice and application of concepts and elicited mainly a single posting response from students. The tasks did not appear to be conducive to generating online discussion. While the possibility of prompting by the teacher and ready access to tools of communication appeared likely to work in favour of increased interaction on the discussion board, in reality the problems of communicating mathematics in online forums and the nature of learning tasks being influenced by curriculum and assessment requirements limited the scope of interaction on the discussion board. Islam and Vale (2005) in a study of the teacher's role in promoting online peer group learning found that when discussion tasks are open ended and controversial and when their content is relevant for students, there is greater likelihood of evoking postings on the discussion board. In our case the discussion board use in the module did not involve open-ended discussion on controversial topics.

As a facilitator of online discussion board activities Cathy's social role expanded to include increased email communication with students and discussion board postings. She appeared to play only a minor role in encouraging students' participation in online postings. The nature of online tasks set by her were not expected to lead to threaded discussions but she played her role as a teacher in using the discussion board as a communication medium with students to provide them feedback and keep them informed about the progress of the course and assessment related issues. It could be argued that different tasks could have encouraged greater use of discussion board communication but course requirements limited our options for discussion board tasks.

Other researchers have also found that in comparison to arts and humanities based subjects mathematics teachers find it particularly difficult to make effective use of online communication channels such as discussion boards and chats (Smith & Ferguson, 2005).

6.4.3 Managerial/ Administrative Role

The managerial role of teacher refers to activities that are designed to make the course run smoothly at an administrative level (Teles, Ashton, Roberts, & Tzoneva, 2001). In typical online courses this means managing course content on the online platform, dealing with enrolment issues, coordinating posting and marking of assignments and assessments and setting clear objectives and agendas for online discussion and conferences (Mason, 1998). In this study Cathy had to play a significant role at the administrative, organisational and course management levels.

With respect to the managerial role Cathy was playing a lead role in initiating this innovation in teaching within her department, she had to convince her head of department about potential benefits of teaching this mathematics module in a blended online format and obtain approval for trying this design experiment with her mathematics class. She was able to convince her program manager easily because this innovation was closely linked to the flexible learning policy advocated by funding bodies in the vocational education sector. She was offered encouragement by her department by being nominated for professional development training in online learning and received a laptop computer to assist in her work. She was given material and moral encouragement but no time allowance was given for her efforts in planning and implementing an innovative delivery in a blended learning format. Cathy pointed out that, “I didn’t get any time off teaching to do it. It was on top of everything else that I do”. In her role as a teacher she took additional responsibilities for gaining management support and approval for necessary resources to teach mathematics in a blended learning format.

In her managerial role Cathy also had to make efforts to ensure timetabling arrangements and class allocations allowed for smooth functioning of her blended learning class. She needed to secure a computer laboratory allocation for her mathematics class. She reported that for her mathematics modules she insisted on having at least one part of weekly lessons in a computer lab but it was not always possible due to room allocation problems. For this blended module she had her manager’s support in obtaining a computer laboratory allocation. This situation shows that for mathematics teachers working in the VET sector, it is not always easy to get a computer laboratory for their mathematics classes.

Cathy also had to take responsibility for organising the course resources for blended online learning. She organised the allocation of a WebCT space for her mathematics module and registered her treatment group students for online learning via WebCT. As a teacher Cathy’s managerial role also included monitoring and uploading of course related materials on WebCT on a weekly basis. On one occasion, she confided that she posted answers to problem exercises for students from a cyber café while on a weekend trip in the outback. She also had to monitor postings on the discussion board and reply to email queries. In this way, as a mathematics teacher her managerial role expanded to include many more responsibilities that were not part of her previous experience of classroom teaching.

6.4.4 Technical Role

The technical role of teacher is closely intertwined with pedagogical issues and involves choosing appropriate software for online learning, designing online content and supporting students in becoming competent in the use of selected technology (Teles, Ashton, Roberts, & Tzoneva, 2001). Research in online learning shows that when a teacher is able to facilitate a smooth use of online technologies students are able to concentrate on the academic task of learning (Bonk, Kirkley, Hara, & Dennen, 2001).

However, the issue of how much technical skill a teacher needs to have to successfully deliver online learning is debatable. In many situations the teacher does not need to perform many technical roles in person because other support options are available in organizations. Research in the VET sector has shown that the successful integration of flexible and online technologies in learning requires more than technical skills; it requires careful consideration of instructional design in online learning environment and new pedagogical approaches based on teaching and learning theories that are in keeping with emerging understanding of online learning (Brennan, 2003; McKavanagh, Kanes, Beven, Cunningham, & Choy, 2002; Stehlik, Simons, Kerkham, Pearce, & Gronold, 2003). In both the first and second cycles of this study the teacher's technical role involved not only to deal with the access, hardware and software issues but also involved issues related to instructional design and selection of online tools and resources for classroom use in learning activities.

Although current mathematics education research literature from the school sector does not address the issue of online learning in mathematics in particular, teachers' attitudes and instructional beliefs regarding pedagogy and the use of technology appear as important factors contributing to successful integration of technology in classroom learning (Handal, 2004; Norton, McRobbie, & Cooper, 2000). From a socio-cultural analysis of learning to teach mathematics with the help of technology Goos (2006) has applied Valsiner's (1997) zone theory to develop an understanding of teachers' work in using technology to teach mathematics in secondary schools. Relating this theory to the context of vocational education Vygotsky's (1978) zone of proximal development (ZPD) can be thought of as the presumed space between teachers current knowledge and skills in making use of the technology to teach mathematics effectively and the potential knowledge and skills she can attain with assistance from professional development opportunities, mentoring support, training etc. Similarly, Valsiner's zone of promoted action (ZPA) for a teacher of mathematics in vocational education may represent institutional policies such as promotion of flexible and online learning in the VET sector and the issues of students' attitude to learning, motivation and assessment policies could be viewed as elements relating to the zone of free movement (ZFM). Goos (2006) notes that for effective professional development a teacher's ZPA needs to be located within her ZFM and be consistent with her ZPD.

In the context of this study the teaching of a mathematics module with a mix of face-to-face and online learning provided direct relevance for learning new technology skills. Cathy was an enthusiastic and keen participant in online flexible learning and followed professional development opportunities to improve her technical skills with computers and online learning. Cathy's technical role in the teaching of this mathematics module involved design, integration and coordination of technology.

Firstly, at the technology design level Cathy had to take part in the design process for creating the WebCT home page for the mathematics module. She had become familiar with using WebCT during her professional development course in online learning. As an experienced user and designer of WebCT I played a mentoring role in helping Cathy learn and design the mathematics module website on WebCT. Cathy and I spent three sessions together during the semester break and completed the first draft of the WebCT home page for our module. During these sessions Cathy gained designer level skills for WebCT and learned how to upload and format content pages, how to create discussion threads and manage discussion board postings. Although I assisted her in designing the WebCT home page for the module and provided professional development as a mentor in helping her become familiar with WebCT tools and resources, she took responsibility for content development and uploading. Resources and class exercises were uploaded on WebCT on a weekly basis and as the course progressed Cathy uploaded new learning resources. In this way, Cathy and I worked closely in ensuring that students were able to access course related material in a timely fashion.

Cathy was well aware of her ZPD in terms of WebCT skills and remarked that, “well I certainly need a lot more professional development for the WebCT”. She was aware of the implications of her own confidence with technology on students’ learning. She pointed out, “I certainly feel more confident to approach it myself and I think the more confident I am then I’ll be in a position to make a change to students I teach it to”. It seems that the designer level access and training to use WebCT as a designer led to the increase in Cathy’s confidence with online learning. As a mathematics teacher she had to invest considerable time in learning new technologies to be able to integrate online learning in her mathematics class. In this situation the ZPA factors appeared to be consistent with her ZPD in learning new technology skills to teach the module in a blended learning format.

Secondly, at the technology implementation level Cathy had to work with her curriculum content and find ways to complement print based learning with online learning. Working within the framework of organisational IT infrastructure Cathy had to use WebCT software platform for the online component of her module. WebCT offers a range of technological tools for content presentation, communication, testing and assessment but also imposes constraints in terms of layout and design for teachers

(Oliver, 2004). Cathy's technical role included learning about these tools and making decisions about their usability for her teaching approach and module content.

At another level, Cathy also had to test and evaluate various web-based mathematics resources to assess their usefulness and suitability for her mathematics module. She was able to draw on her experience of MCA online resources and findings from the previous cycle of this study to identify and select online mathematics resources.

The evaluation and integration of web-based resources for the module took place on a continual basis during the semester and online learning tasks and activities for different topics included references to these web-based resources. In order to maximise their effectiveness only those web-based resources were selected that provided direct access to interactive learning objects and allowed users to interact with the object by providing some user control and instant feedback. Cathy pointed out that the integration of web-based learning has had a positive effect on students but appeared tentative about its effectiveness:

> *It has certainly made a little bit of a difference in students that weren't prepared to do the work, once they got a little bit engaged they were willing to try…in order to make it more effective in the future I think that we have to prepare the students for this type of learning before engaging in it and perhaps in our assessment we should do more, there should be some more online tasks.*

Technology integration was most problematic when it came to assessment tasks. Cathy was very receptive to the idea of having online activities on a topic to complement and extend classroom-based learning and provide students more opportunities for learning. She was also very keen to bring authentic learning experiences via the use of web-based links and resources and her online activities required students to work with real world and authentic data from the field of business and finance. However, integration of web-based activities in assessment tasks for mathematics was a more challenging task. Firstly, curriculum integrity of a CBT module prescribed through learning outcomes demanded a more traditional form of assessment and designing online assessment tasks to meet performance standards required by learning outcomes was something Cathy could not resolve during this trial. Secondly, valid comparisons between control and treatment group performance demanded that assessment tasks for two groups be similar. As a result, only two assessment tasks had a component of online activity and the rest were totally print based assessment tasks requiring short answers. With respect to her technical role Cathy appeared to discover the complexity of assessment in online learning and noted that:

> *… in order to make it [blended learning] more effective in the future I think that we have to prepare the students for this type of learning before engaging in it and perhaps in our assessment we should do more, there should be some more online tasks.*

In trying to integrate online learning with face-to-face instruction Cathy had to deal with competing agendas. One the one hand, the opportunities afforded by new technologies offered freedom to explore new learning activities and tasks but on the other hand assessment constraints limited integration of online activities in assessment.

Finally, with respect to her technical role Cathy had to deal with day-to-day technology issues related to the online component of learning. This required her to attend to students' problems with software and computers and often meant that she had to seek help from the IT department. For example, at the start of the module a number of students were unable to log into WebCT due to incorrect user ID and password. Cathy contacted the WebCT administrator to solve this problem by correcting students' login details. On occasions Cathy was unable to attend to student's technical problems due to her focus on teaching and students had to help each other out. It is seen with online learning that the demand for technical assistance drops as teacher and learners become more familiar with technology being used (Anderson, Rourke, Archer, & Garrison, 2001). During this study also it was noted that most technical issues arose in the first three weeks of the course and once these were resolved students were able to work with the online interface without any technical problems. There was a clear difference between the technical assistance needs of mature age students and youths in the class. Choy and Delahaye (2002) in their study note that young adult learners show different orientation to adult learning principles (Knowles, 1980) and while they prefer the social aspect of adult learning they rarely think about their own roles and responsibilities as learners. Cathy also noted this difference in relation to technology use and support and noted:

> *The mature age students were not so good in their technology, they were actually more [committed], they had a mature attitude to it and they were the ones who were trying to access work outside of the classroom, the younger ones were quite fast, they were more prepared to take it on but then it's how they used it that differed. Adults are better with time management as well…the younger ones are prepared to take it on but 'I'll do it later when I get home' but they never get around to it.*

In the role of technical coordinator Cathy did not present herself as an expert to class and attempted to resolve technical issues through seeking help from more able students and other teachers. She was aware of her role as a mathematics teacher and knew that solving computer and technical problems required mastery of different skills. She took preventive actions to ensure that computers were working properly before classes started and took advice from IT support. She understood that providing technical assistance in class is an onerous task and encouraged students to help each other with such problems. Solving these technical problems in class created opportunities for student - student and student - teacher interactions where dynamics of classroom interaction changed and Cathy's perceived role as an expert changed to a fellow collaborative learner.

Cathy demonstrated an ongoing interest in using technology to bring a change in mathematics teaching in her business mathematics modules. She was cognisant of new developments in the VET sector that could have exerted undue pressure on teaching of mathematics as a stand-alone module (Department of Education Science and Training, 2002; FitzSimons, 2003). For example, with the new national training packages literacy and numeracy skills were embedded in competence statements and training providers did not have to offer separate mathematics or literacy modules (Felsman, 2007). In personal conversations Cathy expressed her concern that mathematics modules may come under pressure with the implementation of new training packages and mathematics teachers may be required to teach subjects other than mathematics.

Stehlik et al. (2003) in their report on professional development of contract and casual staff involved with flexible learning note that many staff take part in professional development to increase their employability and keep their jobs. Although Cathy was a permanent staff member and did not have any immediate threat to her job security it does not appear that her interest in exploring the use of technology in mathematics modules was motivated by employability concerns. Her involvement in the development of MCA Online environment and her involvement in the development and research of blended online learning with her mathematics class without any time release allowance from her department shows that she was committed to improving teaching and learning for her mathematics classes and was aware of the potential of new technologies in learning of mathematics for her students.

6.4.5 Summary

In summary Cathy's role as a teacher was affected by integration of online learning in her module in a number of ways. At the pedagogical level she needed to revise her teaching content to incorporate online activities in mathematics, which allowed her to expand her teaching approach from a predominantly cognitive apprenticeship approach to include exploratory, collaborative and problem solving tasks akin to a constructivist approach. She also used the notions of purpose and utility (Ainley, Pratt, & Hansen, 2006) in her learning activities by creating tasks that necessitated the use of real and authentic data from internet sources. In this context factors related to ZPA such as an emphasis on professional development in online learning in the VET sector helped her in making better use of her ZFM such as access to computers and resources for teaching in an online learning environment. However, it appears that other ZFM factors such as assessment and learning outcome requirements constrained her from engaging in more open ended and authentic problem solving tasks.

Teaching in a blended learning format increased Cathy's administrative responsibilities and apart from ensuring appropriate timetabling and computer laboratory allocations for her mathematics class she also had to deal with administrative issues related to students' accounts for WebCT and manage course discussion board communication. While the online mode increased flexibility of access for students, it also increased demand on

Cathy's time beyond classroom contact hours as students emailed her and responded to her online tasks via discussion board postings.

At the technical level although Cathy did not seem to possess expert level technical skills, her pedagogical beliefs about the usefulness of technology helped her in implementing the blended learning program. She was able to draw on peer support and institution based IT support to deal with day-to-day technical issues with students and acknowledged that she would need to improve her technical skills with online learning to be more effective with the use of online technologies with her mathematics class.

6.5 Attitude towards Mathematics

This section of the chapter focuses on the measurement of attitude towards mathematics and presents results from comparisons of pre- and post-attitude tests results within and between control and treatment group classes.

Our first conjecture in relation to students' attitude towards mathematics was that at the start of the course both control and treatment group students would show very similar attitude towards mathematics and there is likely to be no significant difference between the two groups.

In addition, we also expected that the use of online learning environment in a blended learning format would make a positive effect on students' attitude towards mathematics and as a result our second conjecture in relation to attitude towards mathematics was that there will be a clear improvement in the treatment group's attitude towards mathematics in comparison with the control group.

6.5.1 Pre-test Attitude Comparison between Treatment and Control Groups

Students' attitudes towards mathematics was measured at the commencement of the module using the Aiken Mathematics Attitude Scale (Appendix 2). Results from the attitude scale were analysed for treatment (*n*=14) and control (*n*=15) group students for pre-treatment comparison. The Attitude Scale contained 20 items resulting in a possible score between –20 and + 20.

Table 6.7
Pre-test attitude scores comparison using *t*-test

	M	*SD*	*df*	*t*
Control group (*n*= 15)	5.93	12.03	27	1.21
Treatment group (*n*= 14)	0.50	12.25		

Pre-test attitude score comparison between treatment and control groups using all available scores as shown in Table 6.7 points out that the treatment group (*n*= 14) when compared with the control group (*n*= 15) did not show any significant differences, *t*(27)= 1.205, *p*>.05, two tailed, even though the mean score for the control group (5.93) was higher than the treatment group (0.50).

During the course a number of students dropped out from both treatment and control groups. As a result some students had only pre-test scores available for comparison. By comparing pre and post-test records we discovered that nine students each from the treatment and control groups had taken part in both pre and post testing with the attitude scale. Analysis of pre-test attitude comparison between treatment and control groups using scores for only those students who participated in both pre- and post-treatment tests also shows variation in mean scores (Table 6.8) but again this difference is also statistically insignificant, t (16) = 1.293, p>.05, two tailed, even though the mean score for the control group was higher than the treatment group.

Table 6.8
Pre-test attitude scores comparison using *t*-test for students who completed the course

	M	*SD*	*df*	*t*
Control group (*n*= 9)	7.11	10.88	16	-1.29
Treatment group(*n*= 9)	-0.44	13.74		

Two students from the control group showed high positive attitude towards mathematics with individual scores of a maximum of 20 and it seems that these outlier scores would have caused the mean score of the control group to be higher than the treatment group mean score. Based on these results and observations it could be assumed that the treatment and control groups were statistically similar in their attitude towards mathematics.

6.5.2 Pre-post Test Comparison of Attitude

Using paired sample scores for treatment and control groups a comparison was drawn between pre and post-test scores for attitude towards mathematics. The pre-post treatment group results for *t*-test comparisons show that there was a significant improvement in students’ attitude.

Table 6.9

t-test for pre-post attitude change within treatment and control groups

	Treatment Group (n= 9)		Control Group (n= 9)	
	M	SD	M	SD
Pre-test	-0.44	13.74	7.11	10.88
Post-test	6.78	11.11	11.89	7.36
	$t(9)=2.317$, $p<.05$		$t(9)=1.875$, $p>.05$	

As shown in Table 6.9, attitude change between pre and post treatment scores for both treatment and control groups is positive but mean scores of the treatment group increased more than the control group. Observed results indicate that the attitude of students using blended online learning in the treatment group improved significantly, $t(9)=2.317$, $p<.05$. In comparison control group results indicate no significant difference between pre and post treatment attitude scores, $t(9)=1.875$, $p>.05$.

Table 6.10

Analysis of variance results for attitude scores

	df	F
	Between Groups	
Pre-test	16	1.673
Post-test	16	1.324
	Within Groups	
Treatment Group (n= 9)	8	5.37*
Control Group (n= 9)	8	3.52

* $p < .05$

Pre and post attitude scores comparison was also done using analysis of variance (ANOVA) repeated measures test. Observed F value of 5.368 shows that variation in the means of treatment group scores was statistically significant at the 95% confidence level (Table 6.10). However, observed F value for the control group test shows that the difference in means was not significant at 95% confidence level (Table 6.10). The ANOVA tests also confirm that the attitude of treatment group improves relative to the control group suggesting that the treatment was effective in improving students' attitude towards mathematics.

The post-test comparison in attitude scores shows that the mean score of control group was greater than the treatment group (Table 6.9). It is worth noting that at pre-test comparison also the mean score of control group was greater than the treatment group. However, the results from *t*-test show that the difference in mean post-test scores of treatment and control groups was not significant statistically, $t(16)=-1.151$, $p>.05$, two tailed.

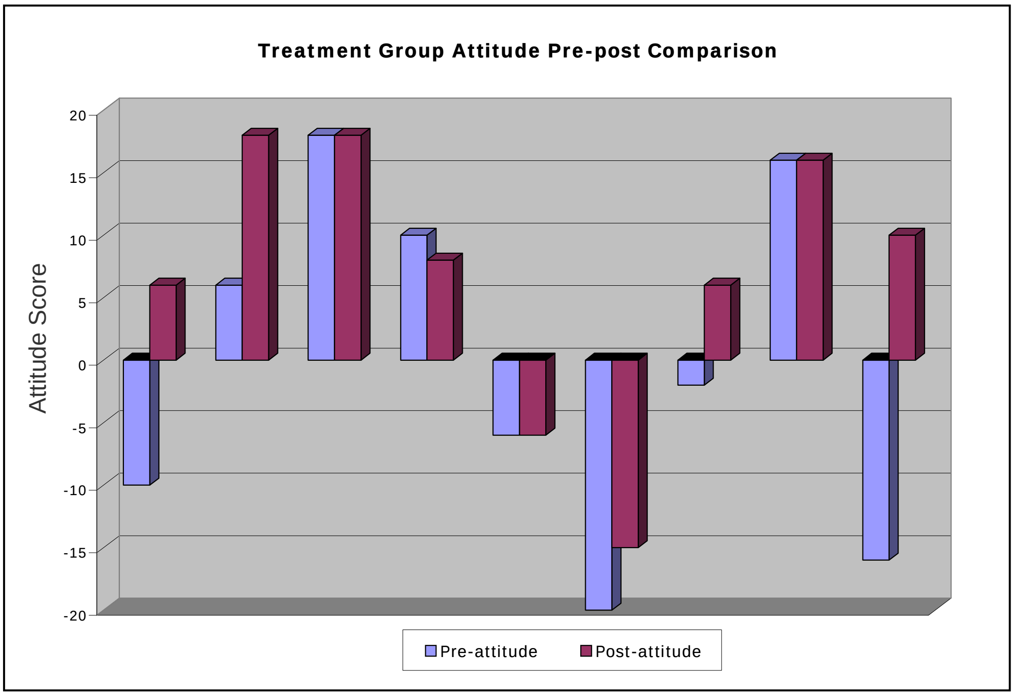

Figure 6.10. A comparison of individual pre- and post-test attitude score for the treatment group students (*n*= 9).

The difference in relative improvement of attitude scores for the treatment and control groups can also be observed in the comparison of individual pre and post attitude test scores for the two groups as shown in Figures 6.10 and 6.11. In the treatment group class there was an improvement in the attitude score of six out of nine students who completed both the pre- and post-tests. The attitude score of remaining two students did not change while the attitude score for one student dropped by two points. Of the six cases for whom the attitude score improved, in at least three cases the score improved by a margin greater than ten points on the scale.

Figure 6.11 which represents the control group pre and post attitude scores also shows that there was an improvement in the scores of six out of nine students, but in this group the attitude scores of two students dropped compared to their pre test scores and one student's score did not change. In the control group class the attitude score of only one student improved by a margin of greater than ten points on the scale.

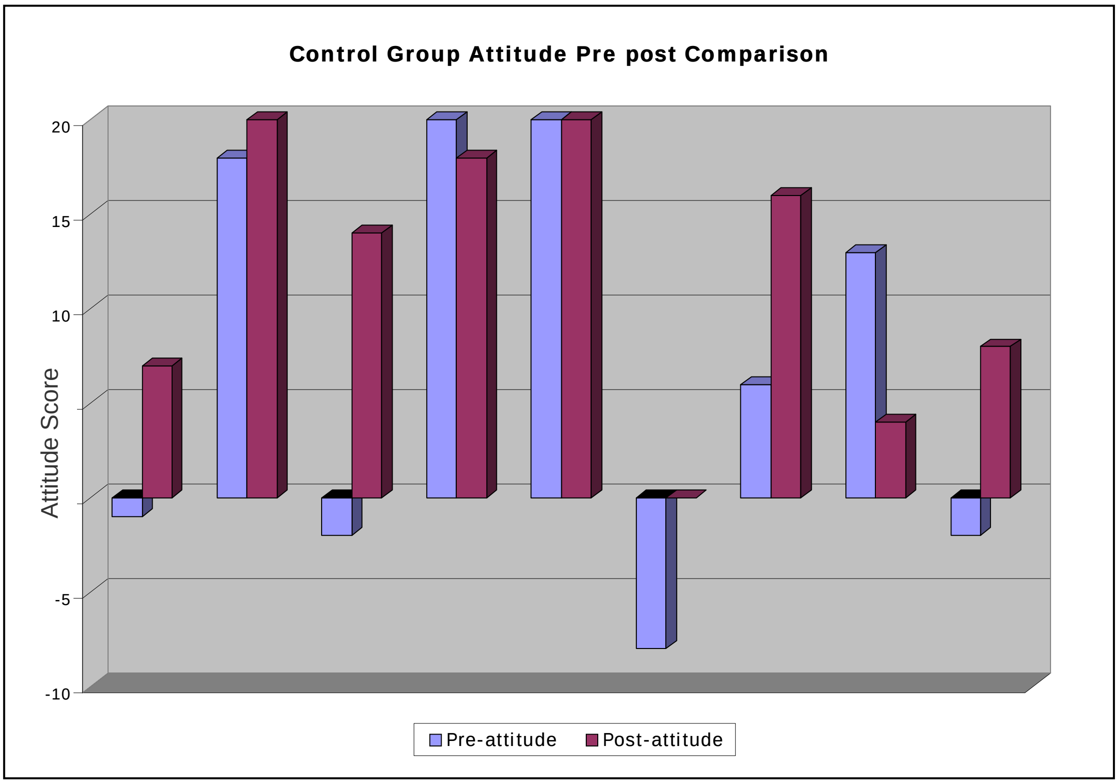

Figure 6.11. A comparison of pre- and post-test attitude score for the control group students (*n*= 9).

In summary, the analysis of attitude scores at the pre-test using t-test comparison of mean scores showed that treatment and control groups were similar in their attitude towards mathematics and there was no significant difference in the attitude scores between the two groups. However, when pre-test scores were compared with post-test scores for both treatment and control groups it was noticed that mean score for the treatment group increased more than the mean score for control group and the difference was significant. This finding suggests that online blended learning was a positive influence on students' attitude in mathematics.

However, it is also important to note that with the sample size being very small it is difficult to attach much importance to the statistical significance of the difference in attitude. Also, although the treatment group seems to have improved their attitude more, it would be incorrect to assume that the intervention was the only contributing factor for this improvement.

6.6 Achievement

This section of the chapter focuses on students' performance in mathematics as measured by classroom tests. Students from both the treatment and control groups were administered a general mathematics achievement pre-test at the start of the course (Appendix 3) and a final test for the module at the end of the course (Appendix 18). The purpose of the general mathematics pre-test was to establish if the two groups differed significantly in their mathematics ability at the start of the blended learning program. Students also completed six bi-weekly assessment tasks as discussed in Chapter 5.3.

Our first conjecture in relation to students' achievement in mathematics was that at the start of the course the mathematics achievement scores of both groups would be very similar and there will be no significant difference between the two groups when their pre-test achievement scores were compared.

At the end of the semester mathematics achievement scores of both groups were once again compared using their final test scores (post-test). The final test was different in content and difficulty from the general mathematics achievement pre-test and aimed at testing students' knowledge and skills on the subject matter learned during the course. Since students in the treatment group were using additional online learning resources and activities in a blended learning format we expected them to perform better. Consequently our second conjecture in relation to students' achievement in mathematics was that the treatment group students would have significantly higher post-test achievement scores when compared with the control group.

Data obtained from pre-test and post-test measurements was subjected to *t*-test analysis for the significance of difference in mean scores between two groups. In addition, analysis of variance (ANOVA) and Pearson correlations tests were also performed to ascertain the significance of any difference in pre-test and post-test mean scores and whether the post-test scores were strongly correlated with pre-test scores. Results from these tests are explained in the following sections.

6.6.1 Pre-test Comparison of Achievement Scores

Students from both treatment and control groups participated in a general mathematics achievement test at the start of the course to find their pre-test achievement scores and if there were any significant differences between the two groups in terms of their mathematical performance. The test consisted of ten questions drawn from topics of number skills and algebra pre-requisite for the module (Appendix 3).

The pre-test achievement comparison between treatment and control groups using all available scores showed no significant difference, $t(27) = 0.114$, $p>.05$, two-tailed as shown in Table 6.11.

Table 6.11
Pre-test comparison of achievement scores using t-test

	M	*SD*	*Df*	*t*
Control group (*n*= 15)	30.42	16.44	27	0.11
Treatment group (*n*= 14)	31.18	18.42		

When comparison was made between two groups using scores for only those students who participated in both pre and post achievement tests the mean scores for the treatment group was 33.12 compared with the mean score of 27.14 for the control group, but the *t*-test statistic shows that this difference was statistically not significant, $t(13) = 0.636$, $p>.05$, two tailed (Table 6.12).

Table 6.12
Pre-test comparison of achievement scores using t-test analysis for students who completed the course

	M	*SD*	*Df*	*t*
Control group (*n*= 7)	27.14	16.24	13	0.54
Treatment group (*n*= 8)	33.13	20.18		

Analysis of Variance (ANOVA) analysis for pre-test achievement scores between treatment and control groups shows an observed *F* value of 0.405 (Table 6.13) suggesting no significant difference between treatment and control groups for the pre-test achievement scores.

Table 6.13
Analysis of variance results for achievement scores students who completed the course (*n*= 15)

	df	F
	Between Groups	
Pre-test	14	0.41
Post-test	14	0.58

Pre-test scores of both treatment and control groups showed that the two groups were very similar in their mathematical ability and skills as measured by the general mathematics achievement pre-test. It was important for the design of the study that the two groups were statistically similar in their mathematical ability at the start of the module to enable a fair comparison between the two groups at the post-test.

6.6.2 Post-test Comparison of Achievement Scores

Post-test achievement test consisted of the final test for the module and comprised of questions taken from all topics covered during the module. It was a different test from the test given at the start of the course as students' final grades for the module were determined on the basis of this final test. Analysis of post-test scores was conducted using *t*-test and ANOVA measures to determine the significance of difference between the mean scores of treatment and control groups.

Table 6.14
Post-test comparison of achievement scores using t-test

	M	*SD*	*Df*	*t*
Control group (*n*= 7)	69.14	20.04	13	0.76
Treatment group (*n*= 8)	60.63	22.96		

Results obtained from *t*-test shows that the mean score of control group (69.14) was greater than the mean score of treatment group (60.62) but this difference in mean scores was not significant, *t* (13) = 0.760, p>.05, two tailed as shown in Table 6.14. The results suggest that the use of blended online learning innovation with the treatment group had no significant effect on their achievement scores in comparison with the control group who had completed the module taught using traditional teaching methods.

When post-test scores on achievement were compared using the ANOVA measure an observed *F* value of 0.577 was obtained again suggesting that no significant difference existed between control and treatment group scores at post-test stage (Table 6.13).

An analysis of covariance (ANCOVA) using achievement post-test scores as the dependent variable, teaching groups as the independent variable and pre-test scores as a covariate, also failed to confirm any significant difference between treatment and control groups with an observed *F* (14) value of 2.263. This analysis suggests that even when achievement pre-test scores are treated as a covariate in order to reduce their influence on post-test comparison, it produces no significant difference between control and treatment group post-test achievement scores.

In terms of achievement scores, there was no significant difference between the treatment and control group post -treatment achievement scores. Statistical analysis based on final test results indicates that instruction using blended learning approach may not have had any impact on students' performance in mathematics. On the surface these results are consistent with research findings reported in literature but there are some interesting observations to be made upon a closer examination of these results.

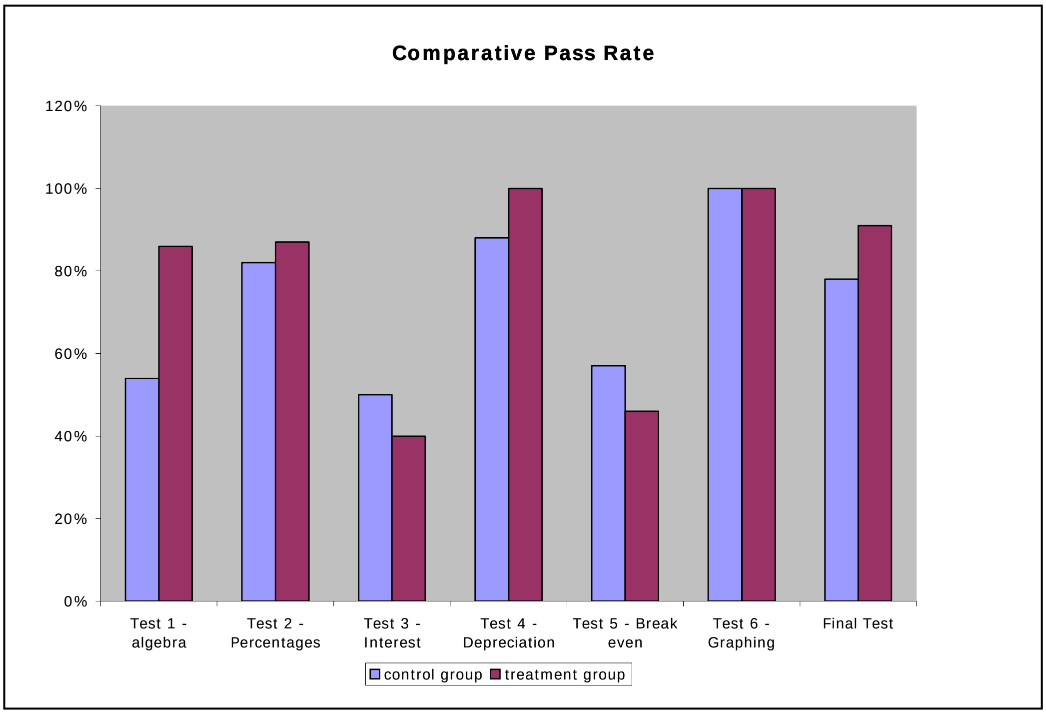

Figure 6.12. A comparison of pass rate between treatment and control groups on bi-weekly assessment tasks.

In our study the post treatment final test for the subject was a paper based conventional test and took no account of the learning with online technology. Interestingly, in bi-weekly ongoing assessment tests where some tests included online tasks, the results were different (Figure 6.12). Results from bi-weekly assessment tests show that on at least four occasions the treatment group had a better pass rate than the control group. Arguably, for the two tests where web-based activities were integral to assessment tests (weeks 1 and 4) the treatment group students had a clear lead in pass rate scores.

In summary, the measurement of achievement scores at both pre-test stage and at post-test stage did not show any significant difference between the treatment and control groups. Since students' final assessment was used as a post-test and it was different from the pre-test, a comparison of mean scores between pre-test and post-test could not be used as a valid measure for effectiveness comparison. The treatment group class was taught using blended online methods and alternate learning activities and resources were used in teaching the treatment group but when comparisons were made on the basis of post-test scores no significant difference was found between achievement scores of the treatment and control groups. The testing conducted for pre and post-test scores was based on traditional print based questions and required students to read worded mathematics problems and apply appropriate formulas and processes to calculate the answer. Although during the study we had hoped that by participating in online activities and doing practice questions in online mode students would show relatively higher levels of achievement in paper based testing and assessment for the treatment group, the results from post-test comparison did not show that this occurred. However, it was clear from the comparisons of mean scores that blended online learning did not do any harm to the treatment group and there was no negative effect of using online learning activities on their results. It can be argued that blended online learning affected the design and content of learning substantially for the treatment group and traditional assessment methods were unable to account for gains achieved by the use of blended online learning methods as presented previously in chapter 5.4 and discussed further in the next section.

6.7 Blended Online Learning and Assessment

This section of the chapter focuses on the issue of assessment and how teaching and learning in a blended learning environment creates challenges for assessment in mathematics. The blended online learning model offers a unique mix of face-to-face learning complemented by the use of web-based tools, resources and communication (Brown, 2003; Cashion & Palmieri, 2002). Integration of online activities in a campus based face-to-face course adds new dimensions to the content and pedagogy of learning. It helps to bring more authentic and real life learning tasks to classroom, prepares students to work with new technologies in their chosen field and provides opportunities for problem-based learning. However, when only traditional assessment methods are used to assess students' knowledge and performance in a subject taught by a blended online method, gains, if any, achieved by the use of new methods could remain largely ignored and unaccounted for in the final analysis.

In this study the treatment group was taught using both online methods and face-to-face traditional methods but final assessment test was offered only as a pen and paper test with no reference to online resources and applications. It required students to read, interpret and understand a set of print-based problems and expected them to write short answers and solutions within a given timeframe. The control group was also administered the same final assessment test and results were compared. Final test scores comparison between the treatment and control groups showed no significant difference in performance between two groups (see Section 6.6). On the surface it could be assumed that applying blended learning format with the treatment group did not have a positive effect on students' learning in mathematics. But a closer look at learning activities and the formative assessment conducted during the course shows that when the teacher included online tasks for assessment, students' participation and performance were better compared to their paper based assessment scores (see Chapter 5.4.2.2). However, when performance is measured using traditional pen and paper methods, the control group students appear to show slightly better results. One student who favoured the use of computer based tasks for assessment said:

It (assessment) is good, you've got both computer work and writing work as well, you've got a balance of things it's not just writing the whole time, you've got the *computer too...Well I'm probably advantaged to some people who don't have computers or the internet at home. But I'm favouring it.*[Interview transcript: student - Juang]

The purpose of the module that provided the context for this study was to provide the learner with the knowledge and skills to apply mathematical techniques to a variety of business applications and decisions. The learning outcomes required that students be able to solve basic linear equations, use a calculator or computer to perform common commercial percentage calculations, perform simple and compound interest calculations, perform basic depreciation calculations, apply the principles of linear equations to break even analysis and prepare appropriate graphs from data and interpret them.

During the study a number of online mathematics activities were integrated with face-to-face teaching. These online activities served two important but different roles. One type of activity focused on skill building and comprised interactive java applets and programs. Students used this interactive practice to reinforce particular mathematical skills such as transposition or order of operations. The other type of activity involved problem solving and investigations that invited students to explore mathematical concepts and skills by using online communication, web tools and knowledge archives. In the following section I will describe and point out how learning afforded by online tasks extended students' knowledge and skills and when assessment relied only on traditional assessment tasks these new dimensions of learning remained largely unaccounted for.

6.7.1 Drill and Practice in an Online Environment

Firstly, let us take the case of drill and practice type online activities. These are activities where online technology provides a non-intrusive interactive tool to practice a specific mathematical skill. For example, during the first session on algebra the teacher started the session with a face-to-face teacher directed segment where simple algebraic equations were solved on the whiteboard. About midway through the session a transition was made from the face-to-face teaching to online activities. The online program offered a transposition equation to the user and asked for an answer. Students had to work out the problem either mentally or using pen and paper, and type their response on the screen. The program checked the response and returned a screen with feedback and correct solution. Lesh and Doerr (2003) point out that mastery of basic skills and procedures to solve certain mathematical problems efficiently is a desirable learning goal. Research has also shown that auto correction activities allow students to notice their errors and attempt remedy without intervention by the teacher, and students are less anxious about their mathematics skill when unsupervised (Delors, In'am, & Roberto, 1998). In this session we observed that during the online activity students were able to take more risks in attempting solutions and moved on quickly to attempt the next problem. They also appeared more willing to ask their peers for assistance when unable to find a reason for their errors in solving problems.

Class observation and WebCT logs from this session indicate that students' engagement with this activity was positive and by attempting the interactive exercise as many times as they liked some students were able to self-correct their errors in solving problems. Students' transposition skills seem to improve after this exercise and they used these skills in solving paper-based transposition problems. Final assessment test questions on this topic included print based questions where students had to transpose equations similar to those practised in the online activity. The advantage of online practice on this type of problem is clear from both weekly assessment result on algebra topic and also comparative performance on this problem in the final test (see Section 5.3.2.2). In this example, due to close similarity of online practice task and print based equations task, it can be argued that students had the opportunity to apply skills mastered in online environment to offline print based tasks. However, this is not true for most other situations where online activities did not have a direct and parallel offline print based task.

6.7.2 Writing Mathematics in an Online Environment

The introduction of online activities created opportunities for writing mathematics and learning symbolic representation of mathematics in the online medium. In these online activities students developed their skills and abilities in communicating mathematical ideas both in a symbolic form in online activities and in text form in online postings.

For example, in an online algebra activity students were required to input their algebra equation in a java based program and let the program solve the problem. In this activity students were required to use ASCII equivalent symbols for mathematical operations and many students were totally unfamiliar with representation of mathematical operations in these symbolic forms. For example to type a fraction in an exponent form such as $x^{2/3}$ students needed to type *x*^(2/3). The teacher provided clear instructions with examples of mathematical expressions for web-based tools.

In another online algebra task students were asked to create a word problem based on a simple algebra equation. They had to post their problems on an online discussion board where other class members could see the problem and attempt solving and posting solution to it. The teacher presented this problem as a cooperative activity where students had to learn the language of writing algebra problems and think about everyday situations that can be used as a basis for creating worded problems. During this session students actively engaged in using the online discussion platform to post their questions and responses to other postings. This task was a new learning activity generated specifically for the online environment and although it did not involve solving typical algebraic problems, students had to position themselves as a problem generator and think about situations where an algebraic relationship could be created. A selection of sample postings is given:

> Example 1
>
> *Tony worked at the Albion fun market. His business specialised in seling mens shoes. If Johanny bought 15 pairs of formal shoes costing him a total of $450. the shoes would have origainally cost Johanny $600. but since johanny and tony were good friends he gave him a discount of how much? The fun market quiz is to find out how much discount was given?*
>
> Example 2
>
> *Tony worked at Malvern Post office he works 25 hours on weekdays on a normal average rate of $14.57 per hour and works 5 hours on Saturdays which*

is a rate of one-a-half the normal rate. Tony also took some stamps home valued at $9 which will be deducted from his pay.
How much wages is Tony going to get this week? All the best of luck to everyone solving the problem.

Example 3

It's half time here at the "G", and we have witnessed a fierce clash between the traditional rivals the Moscow Moo-Cows and the Adelaide Gerbals.

We have witnessed a total of 99 points scored at the great stadium this afternoon, of course 6 being awarded for a goal and one for a behind.

The Moscow Moo-cows have kicked a total of 66 points, including 10 goals.

The Adelaide Gerbals have kicked 10 behinds in their first-half score.

Can anyone out there at home tell me

a) How many behinds did the Moo-Cows kick for the firsthalf?
b) What was the Adelaide Gerbals Total first-half score?
c) How many goals did the Gerbals kick in the first half?

The selection of postings above shows students' imaginative use of everyday situations to create a context for algebra problems. Although, the task of writing mathematical problems on the topic of solving algebra equations did not provide direct practice for equation solving skills, Cathy included this task to give students a chance to see and experiment with relationships with numbers and quantities in everyday situations. Research on writing mathematics shows that writing word problems is a powerful tool for learning algorithms (Fennell & Ammon, 1985). Students who practise writing worded problems on algorithms appear to have a greater sense and understanding of the meaning behind an algorithm (Golembo, 2000).

The online activities on the topic of algebra led to an active use of the discussion board immediately after the face-to-face sessions and generated 44 postings from students. The online sessions also provided students with opportunities to practise equation solving, using symbols for mathematical operations and reasoning and language associated with generating worded problems. But as far as assessment is concerned, the traditional test format used for the final test focussed only on traditional print based algebra questions and placed no value on a deeper level of understanding of concepts offered by tasks such as writing word problems. Interestingly, the task of writing worded problems could have been used in a face-to-face pen and paper based learning environment as well but the online discussion board made the job of posting and sharing problems with each other much easier than is possible in a pen and paper based learning environment.

6.7.3 Searching and Locating Mathematical Knowledge Online

The Internet offers vast archives of mathematical knowledge and new interactive tools to perform complex calculations. Modern banking, finance and trade practices make use of these web-based interactive tools in their daily practice (Gunningham, 2003; Zevenbergen & Zevenbergen, 2004). Collaboratively developed knowledge repositories are also becoming increasingly popular. In the field of mathematics, questions and answers archive developed on *Ask Dr Math* website is a unique collection of mathematical knowledge derived by student-teacher questions and answers on various maths topics from primary to university grade students.

Considering the relevance and appropriateness of these online resources for her students Cathy included a number of online activities on the topic of percentages and interest where students had to search and locate information to solve a given problem. For example Cathy posted a problem activity on the discussion board after teaching the topic of simple and compound interest in a face-to-face session. In this activity students were asked to search and find a popular business mathematics rule and test it with problems from their exercises (see Chapter 5, Section 5.4.3).

In the context of learning mathematics in a blended online environment this activity proved to be very successful in opening up a new avenue of knowledge seeking for students. They learned to locate and find answers to their problems from an online archive built with the help of an online community of mathematics teachers and students. It was interesting to note that this activity forced many students to focus on estimating their answers with a quick mental calculation. Use of mental calculations in estimating answers is increasingly emphasised in research literature, especially when students are relying on calculators (Goos, 2002; Gunningham, 2002).

Similarly, in another online activity during the topic of percentages students were expected to make use of online calculators to explore mathematical relationships between different variables. In one task students were asked to use an online home loan calculator to explore the effect of frequency of loan repayment on loan period. Students were also expected to learn to use these calculators to work out borrowing limits and repayment amount for various scenarios. Obviously here students are not using pen and paper to manipulate variables in a given algebraic algorithm. Instead, they are using the efficiency of automation afforded by an online calculator to explore mathematical relationships between different variables applied to a home loan context. Research by Hoyles and Noss (cited in Ainley, Pratt, & Hansen, 2006, p. 29) has labelled this way of using technology as 'using before knowing' and they claim that students' use of technology in meaningful ways empowers them to learn mathematics.

During this task initially many students could not work out the problem correctly because of their inexperience in manipulating screen based variables where some fields required numeric entries and other fields expected users to choose from a drop down list of choices. Some students also struggled with repeating online calculations by changing just one variable because applying reset calculation resulted in all entries being wiped blank. It required some careful observation and understanding of how various inputs impacted on the calculation. But once this aspect was mastered, students showed a keen interest in experimenting with various combinations of variables. Although by using the online calculator students did not have an opportunity for learning the mathematical processes involved in home loan calculations, classroom discussion after the activity revealed that the exercise had assisted students in learning about the relationship between different variables and how various home loan amounts were affected by changing these variables.

One of the advantages of doing online tasks in a classroom situation was that Cathy was able to switch between face-to-face and online mode to explain a particular concept. For example, in teaching compound interest problems, Cathy first used tabular method to demonstrate how interest is added to principal to calculate interest for the next period. Later she helped students derive the formula to calculate compound interest and gave them questions to practise manual calculations. So, when students moved to the online calculators for interest problems they had already done some practice with paper based questions. Therefore students' experience of online calculation was not constructed with the view of "technology as master" but rather "technology as partner" (Goos, Galbraith, Renshaw, & Geiger, 2003). Given the skills learned with the compound interest algorithm students were able to calculate solutions for standard problems but the online calculators brought in the convenience and efficiency of calculations to explore relationships between various variables.

The efficiency afforded by online calculators allowed students to explore relationships between variables which would not have been achieved using pen and paper in the given timeframe. These online activities provided students opportunities for exploring and investigating various patterns and relationships between different variables involving topics such as currency conversions, interest rates, depreciation and linear graphs. They also learned the skills of using these online tools to solve realistic problems from their exercise sheets (see Chapter 5, Section 5.4.4 and 5.4.6).

Students' exploration of online archives and the acquisition of skills necessary for seeking knowledge and understanding from these sources points to new dimensions of learning afforded by a blended online environment but traditional assessment tasks lack the intent and design to be able to account for these dimensions of students' achievement.

As part of a number of online activities students were required to conduct web searches for specific mathematical tools and calculators, and evaluate their usefulness for carrying out specific calculations. One of the main things about using these online calculators was the requirement that students be able to estimate their answers and compare it with their computed results. During the topic of depreciation, students learned about calculating depreciation by using the straight line and reducing balance methods. Cathy showed them these methods by modelling solutions on the white board and seeking student input while building up a solution. Students learned this method and practised paper based word problems on the topic of depreciation.

During the online session on this topic students were told that they can search and find a range of depreciation calculators on the Internet and students were given the task of finding and using a suitable depreciation calculator to solve given problems. They had to test the functionality of their calculator by solving a set of given problems. As a requirement for this task students were to post the web address and their evaluation of the calculator on the discussion board. As an example a response from a student is shown below:

> Subject: Task1 Financial Calculator
> *I found a great depreciation calculator for working out the value of cars after a number of years, details are as follows:*
> *Car Times Depreciation Calculator*
> *www.cartimes.com/search/depreciation.shtml*
> *It gives you salvage vehicle values after the chosen period.*
> *Example that I did: Car cost 25,000, was bought new, its value after 10 years?*
> *total depreciation = 20,290,*
> *Salvage value = 4,710.*
> *Makes you wonder why some people think cars are any sought of asset. see ya.*
> *[Posted on student discussion board by Jacob]*

A closer look at the posting reveals that working with online calculators to explore mathematical relationships allowed students time to reflect on the process as well as the outcome. His comment that “Makes you wonder why some people think cars are any sort of asset” is a clear indication that this student has been able to put the concept of depreciation in a broader context and show critical numeracy awareness. Surely, when students have to practice these questions in a manual pen and paper mode there is more time spent on algebraic manipulation and computation and there are fewer opportunities available for exploration and reflection.

Despite it being well known that workplace practices are increasingly dependent on the use of technology to perform manual computations, many teachers in vocational and school settings continue to focus an inordinate amount of attention to memorising algorithms and skills practice in using these algorithms. Highlighting the significance of technology in contemporary mathematics teaching and learning Gunningham (2003) in her keynote address to Mathematics Association of Victoria noted that:

> *The era of humans thinking strategically and using estimations that are later supported by error-proof calculation performed by technology is upon us. Yet in many of our mathematics classrooms, little change has occurred in either the curriculum delivered or the manner in which that curriculum is delivered. Students still spend many hours completing a sea of algorithms, each one an almost duplication of the previous one, for little purpose other than to practice an already acquired skill. While this repetition may be a valuable aid to automatic recall, it does not develop thinking and build a network of strategies for solving unfamiliar tasks that the student may confront at another time. Teachers using such repetitive approach are ignoring the new 'big picture', clinging instead to outdated concepts of curriculum that will hinder our students' potential to succeed beyond school. (p. 83)*

Echoing similar sentiments, researchers such as McIntosh, De Nardi and Swan (2004) have also reported that "at least 75% of all calculations" (p. 5) which adults use in daily life are based on mental estimations and calculations rather than use processes learned at school. These researchers value the development of skills of number sense and estimation with numbers more than skill with algorithms.

The method adopted by Cathy in her online class provided students with a unique mix of skills acquisition and exposure to technology tools and estimation. During online activity sessions she frequently referred students to MCA Online units for basic mathematics skills and interactive practice links available from the resource page of the WebCT course home page. During the use of online calculators to perform calculations students were constantly challenged to estimate their answers before actually engaging in the use of technology. In this regard learning key concepts with the help of face-to-face sessions using the whiteboard was invaluable in providing the scaffolding for estimation. The weekly assessment task on depreciation included both online work and paper based calculations, and students' performance on this task was comparatively better than the control group. However, the final assessment task had only paper-based questions on the topic of depreciation and any skills and knowledge students acquired in searching, evaluating, estimating and computing with technological aids accounted for little or no credit.

In summary, the blended online learning class in mathematics included a number of new and innovative activities to provide students opportunities for working with authentic and real life data or tools. These activities helped students to develop a deeper understanding of the concepts learned and to apply them in realistic and work-related contexts. While some online tasks helped students to practice conventional skills with the help of an automated online tool other tasks showed students ways to search for solutions on Internet archives. In addition to learning about finding and using online mathematics tools, browsing online mathematics archives of problems and solutions students picked up important clues for problem solving and estimation skills.

There was also a spin off in terms of learning to use an online learning environment, participating in online discussions, emailing, searching and becoming familiar with mathematics symbols used in an online environment. Clearly, most of this learning is difficult to assess using conventional methods of assessment. We also found that certain weekly assessments where students had an opportunity to engage with tasks that included online components their result was relatively better compared with the control group. Findings from the study offer a clear hint towards the inadequacy of traditional assessment methods to account for learning afforded by online environments. Educators need to recognise the challenge of bringing online learning to mathematics classrooms in a blended format with the view that assessment is an integral part of teaching practice and it must reflect new dimensions of learning afforded by online learning environments.

6.8 Conclusion

This chapter has presented an analysis of the findings emerging from the second research cycle. In an attempt to respond to research questions each section of this chapter has dealt with a particular research question and conjectures related to the issue.

In terms of factors affecting student participation in blended online learning in mathematics findings from this study suggest that students' computer skills, motivation and attitude are important personal readiness factors. A comparison of students' attitudes towards mathematics with their online participation and final results reveals that although students with more positive attitude towards mathematics appeared to score more marks in assessment and final tests, students' participation in online activities was not related to their attitude towards mathematics. In some cases students with a very negative attitude were found to be most active in terms of online participation. However, students with a positive attitude towards mathematics seemed to access the online environment more selectively. The interactivity afforded by online activities and tasks requiring use of authentic and real data appeared to affect students' motivation in participation in learning activities. But, course related factors such as the curriculum load, pace of teaching and lack of time for consolidation of learning seemed to put undue pressure on students and affected their participation in self directed and exploratory activities negatively.

In terms of access to and use of the online learning environment by students the findings reveal that students' access to and use of the online environment was predominantly during school hours and from classroom computers. Students' access to and use of communication tools indicates that they used these selectively to respond to tasks set by the teacher. It appears that the use of an online discussion board to generate social contact was not necessary when the class was able to meet in a face-to-face situation.

The use of an online learning environment affected the teacher's role in a number of ways. It affected her pedagogical role and allowed her to incorporate more engaging, authentic, collaborative and problem-solving tasks in her traditional teacher led instruction. The blended learning approach also offered the teacher professional development opportunities to enhance her technical skills in designing and offering online learning.

While students' attitude towards mathematics seemed to improve for both control and treatment group, after a semester of teaching the increase in attitude scores of treatment group students was significant, whereas the increase for the control group students was not. Students' performance in the final test did not indicate any significant difference between the control and treatment group students, seemingly depicting that the use of online activities in learning did not have any impact on students' performance. But a closer examination of assessment tasks and student results showed that online activities involved different skills and strategies and traditional assessment methods were not suited to assess them. The increasing use of online tools in industry and teaching methods demands a fresh look at assessment practice as well. In the next chapter a discussion of the findings and issues emerging from this study is presented.

Chapter 7: Conclusions and Implications

7.1 Introduction

This study emerged from a perceived need of vocational and further education students to improve their mathematical skills and become familiar with the increasing application and use of new technologies in workplace mathematics. One of the main purposes of this study was to investigate and understand how an online learning environment can be designed and used to support and enhance students' learning in mathematics. The online learning environment was designed to provide opportunities for more engaging and authentic learning activities and aimed at encouraging students to develop techno-mathematical literacies for relevant workplaces. The study also included a practical orientation of action to bring about a change in the practice of teaching of mathematics in vocational education.

Using a design-based research approach the study comprised two cycles. In the first cycle a group of mathematics teachers were involved in exploring Internet based mathematics resources and participated in the design of a website that consisted of twelve units of basic mathematics topics with facilities for both synchronous and asynchronous communication. The online learning environment focussed on providing well-structured navigational scaffolding, interactive tasks, access to authentic data and a communication medium to promote the idea of blended learning where face-to-face classroom activities were expected to be enriched and extended by the use of resources and activities located in online learning environment. Students were expected to access and use the online learning environment from their classroom as well as during outside class hours from their homes. Once the online learning environment (MCA Online website) was ready, it was trialled with a number of mathematics teachers in mainly workshop mode.

In the second stage, the online learning environment was customised for use with a business mathematics module in a diploma course and trialled in a semester long course taught on campus in a blended learning format. Students from a maths class participated in this trial where face-to-face teaching was mixed with online tasks and activities. The online tasks and activities were aimed at enhancing and extending classroom work on selected topics and provided opportunities for communication and flexible learning beyond classroom boundaries. Assessment included both pen and paper tests and some online tasks. Data obtained through classroom observation, WebCT logs, discussion board postings, test results and interviews were used to explore and analyse issues concerning students' participation, access to, and use of online learning environment in mathematic activities. The various pedagogical roles of the teacher in this blended learning environment were examined. These included design of teaching strategies and learning activities, the nature of teacher interactions, the management of blended learning and the design of the online environment. In addition, the factors that motivated, promoted and constrained the teacher's implementation of blended learning were examined using zone theory as adapted by Goos (2006).

This study, which included the development of a web-based learning environment in supporting and enhancing mathematics learning, appears to have made an important contribution in raising vocational mathematics teachers' awareness about potential advantages and the need of incorporating web-based learning activities in their curriculum, teaching and assessment. The web-based learning environment developed during this study continues to be used within the TAFE institute of the study and in other educational settings today and the MCA Online website has been listed on more than 50 international education websites including Yahoo answers, Teacherweb, Scinet and Maths Association of UK websites (refer Appendix 19 for a full list).

7.2 Tentative theories

The study provided an opportunity for a number of vocational education mathematics teachers, including the researcher, during the first and second cycles of this study to explore new learning technologies in teaching mathematics and to gain a deeper understanding of the issues concerned. The tentative theories emerging from findings of this study are discussed in this section.

From a teacher’s perspective the design and development of an online learning environment in mathematics required special tools and skills. Symbols and expressions used in pen and paper based mathematics communication needed cumbersome techniques to place on a web page. In comparison to other subjects, writing and communicating mathematics on the web is more problematic and students need to learn special symbols and codes to express their mathematics using communication mediums such as discussion boards offered by the web. But developments in recent years, such as the use of a mathematics mark-up language (MeML) for creating web-based mathematics content, are promising to offer mathematics teachers better access and means of creating web-based lessons and activities (Wang, Kajler, Zhou, & Zou, 2003; Wang et al., 2008).

Although computer skills were necessary for participating in online activities in mathematics, students’ meta-cognitive skills, such as their ability to monitor their progress and evaluate their learning, rather than their computer skills played a more significant role in determining the extent and quality of their use of the online learning environment. Students having confidence with computers and a positive attitude towards mathematics accessed the online learning environment selectively to gain necessary skills and knowledge needed for completing assessment tasks. They appeared to benefit most from the use of an online learning environment. Students showing a low confidence with computers and a negative attitude towards mathematics seemed to avoid the online learning environment. Consistent with previous research in the mathematics education field, in our study also, students’ attitude towards mathematics did not appear to be associated with their participation in an online learning environment and students with necessary computer skills, despite their negative attitude towards mathematics, appeared to use the online learning environment successfully (Fogarty, Cretchley, Harman, Ellerton, & Konki, 2001; Norton, McRobbie, & Cooper, 2000).

The navigational scaffolding provided in the online learning environment allowed students to access and use the web-based interactive tools and resources from external websites with relative ease. Students did not need to spend too much time in searching. It also assisted them to aovid being distracted by irrelevant web pages and becoming confused while navigating external websites. In designing online learning environments navigational scaffolding that allows learners to access and focus on specific online activities without being distracted by other information plays a key role in their successful experience of web-based learning.

Web-based interactive learning activities that use data input from users to generate solutions, simulations and feedback are highly valued by learners and play an important role in their motivation to learn with this medium. Students appeared more positive in using the system when they could see the consequences of their actions immediately.

However, the pace of teaching and curriculum load emerged as important factors that prevented students from sustained engagement with particular topics in order to develop a deeper conceptual understanding. The curriculum content load appeared to limit students' engagement in self-directed exploratory learning activities in the online environment. They appeared to focus on those tasks that were part of the course assessment plan and affected their result in the module. This finding is consistent with research in the vocational education field that suggests that conventional course design and delivery strategies limit their suitability for online learning (Oliver, 2004).

A blended online learning environment provided flexible and better access to course resources. It encouraged peer-to-peer and student-to-teacher interaction and cohesion within the class. However, flexiblity and better access to resources were not able to counter the attrition of students from the course. Students who attended face-to-face sessions regularly made more use of the online resources from both inside and outside class hours. It appears that, in terms of flexible learning, although students favour flexibility of access to their course materials, in reality, most students make very limited use of these opportunities beyond classroom contact hours. The flexible learning opportunities seems to have little impact on student attrition rates from classes (Gabb, Milne, & Cao, 2006). These findings are consistent with research reporting that vocational educational students prefer blended learning where face-to-face teaching is mixed with online learning tools and resources (Cashion & Palmieri, 2002; McKavanagh, Kanes, Beven, Cunningham, & Choy, 2002; Robertson, 2007).

Although the online learning environment provided greater opportunities for peer to peer and peer to teacher communication the uptake of discussion board and other online communications such as chat and email remained very limited. Students did not take up chat. The discussion board postings were mainly limited to responding to teachers' tasks and any evidence of sustained peer-to-peer communication did not emerge. It appears that the nature of the learning objectives and assessment tasks played a significant role in determining students' use of the discussion board. In addition, as noted in research literature (Smith & Ferguson, 2005) it was more difficult to communicate mathematics via the online communication medium due to problems in writing symbols and expressions.

Students' attitude towards mathematics improved with the use of a web-based learning environment in a blended format of teaching. The study found that students' skills and proficiency with computers and technology did not affect their attitude towards mathematics however students showing more positive attitude towards mathematics performed better in mathematics tests. The use of web-based learning activities in mathematics enabled the teacher to offer more authentic, engaging and collaborative learning opportunities to students and seemed to confirm findings from a similar study (Gunnarsson, 2001) that the experience of using an online learning environment contributes towards building of a positive attitude towards mathematics.

The use of online learning activities in teaching the business mathematics module appeared to have no effect on students' scores in the final test conducted in a conventional paper based mode. It seems that mathematics learning is transformed qualitatively when technology and online resources are used in teaching. In contrast to the conventional approach to learning where knowledge and skills are developed first and applied to problem solving subsequently, it appears that technology rich learning environments provide opportunities to learners to work with concepts that they may not yet understand and allow them to develop an understanding of the concept through use (Hoyles and Noss cited in Ainley, Pratt, & Hansen, 2006).

When reporting on the effect of online learning on students' performance many studies have found no significant difference when employing traditional paper-based assessment tests to evaluate their performance (Gunnarsson, 2001; Yushau, 2006) and it seems that the traditional paper based assessment methods are inadequate to test the knowledge and skills acquired in the new online medium (Ng & Hu, 2006).

7.3 Implications of the Study

This study was undertaken with a view to finding out how web-based technologies can be accessed and used to support and enhance mathematics learning in the vocational education. The tentative theories arising from findings of this study have implications for successful design of an online learning environment for mathematics teaching in a blended learning format and for assessing mathematics learning.

7.3.1 Designing an Online Learning Environment in Vocational Mathematics

The design of the online learning environment in two cycles during this research followed from two different design purposes. In the first cycle the design focussed on creating an online learning environment for teaching general mathematics skills to students who needed to revise and re-learn their basic mathematics while doing their vocational education courses. In the second cycle the design concentrated on developing a module specific online learning environment that provided opportunities to support the learning of specific mathematics content for a particular industry context. The findings from both cycles lead to following implications in relation to designing an online learning environment:

a. Designing web pages with mathematics symbols and expressions is a challenging task for mathematics teachers-designers. Before planning to design an online environment for mathematics it is important to find out how new tools and protocols in web editing allow creation of static (that is, content on the page does not change by actions of the user) and dynamic (that is, content of the web pages changes as a result of action or choice of the user) mathematics lessons and activities on the web.

b. The online learning environment needs to be closely aligned to the vocational education mathematics course and, consequently, industry context to make it effective for students' learning needs. The purpose and utility of online resources for learning in specific contexts is necessary for their meaningful use by teachers and students.

c. Navigational scaffolding that allows learners to locate and access online resources easily is an important design consideration and needs to be incorporated to allow students to access and use the online resource without distractions and being lost on the web. An online learning environment using links to external web pages needs to be frequently revised and updated to ensure that links to external web pages work as desired.

d. Interactivity of online tools and resources that allow users to input their own data and provide immediate feedback is valued by students and increases their motivation and engagement in learning. The online learning environment for vocational students needs to offer learning resources that are relevant to the industry and enable learners to experience simulation of authentic problems.

e. Online communication via electronic discussion boards on mathematical topics is difficult and challenging for VET students due to the need to learn alternate mathematics symbols and expressions. Careful curriculum planning and task designing that encourage online communication are required to engage students and gain value from participation in online discourse. More research is needed on how communicating in online environments may support VET students' learning of mathematics.

7.3.2 Teaching in Blended Online Learning Format

Teaching of vocational mathematics in a blended online learning format where face-to-face teaching is juxtaposed with online tools and activities requires the teacher to play a number of important pedagogical roles and the extent and nature of learning in this format depends on number of factors including teachers' instructional beliefs, knowledge, skills and motivation. Following implications in terms of blended learning emerge from this study:

a. Blended online learning offers vocational mathematics teachers opportunities for creating industry specific authentic learning experiences with access to a range of relevant and easily accessible tools and resources on the web. Vocational education programs need to encourage teachers to explore and adapt blended learning models in their mathematics teaching by requiring proficiency with industry relevant online mathematics tools and solution of authentic problems in virtual environments.

b. Mathematics classes would need to move to facilities where computers are available in classrooms for blended learning to be successfully applied. VET Institutions need to provide technology based environments so that learners can do blended learning.

7.3.3 Assessing Mathematics Learning in VET Courses

A closer examination of the effectiveness of online activities on students' performance in mathematics tests reveals that students using new technologies and online activities in their learning did not show any effect on their results in the traditional pen and paper tests but when their assessment included online activities or tasks in a blended learning environment the success rate was higher. The following implications for assessment practice are noted:

a. Increasing use of new technologies in workplaces requires vocational training to also include the use of these technologies in their training programs. In mathematics learning the use of new technologies transforms the content and nature of mathematics learned. The assessment methods for learning with new technologies and in online contexts need to be different from traditional paper based methods. Mathematics teachers need to look for assessment practices that are able to account for new learning that occurs in blended learning environments.

b. The learning outcomes and assessment tasks for vocational mathematics courses need to be articulated holistically and located in authentic industry contexts. A review of course content and assessment practices in vocational mathematics is necessary to bring about changes in teaching and learning demanded by emerging workplace practices and the use of technology. This view is supported by other recent research in the field of vocational education as well (FitzSimons, 2003; Marr, 2007).

7.3.4 Further Research

In the interest of extending our understanding of the design, application and effectiveness of web-based learning environment in supporting and enhancing mathematics learning in the vocational education teachers and researchers could conduct further research to confirm findings of this study and suggest effective instruction and assessment strategies. Further research in mathematics teaching in vocational education sector with an emphasis on the use of new technologies in learning could extend our understanding. For example:

a. How can new online learning environments be developed and used for teaching mathematical skills required for emerging technology rich workplaces?

b. How is vocational mathematics transformed with the use of new learning technologies and what new assessment criteria and methods need to be developed to evaluate students learning in these new learning environments?

c. The learning environment developed in this research needs to be updated and customised for supporting and enhancing mathematics teaching in other trade and vocational areas. Further research could identify gaps in the learning environment design and implementation process.

d. New tools and technologies are continually becoming available for teaching and learning. It is important to explore how problems in writing of mathematics for web-based learning and communication can be overcome with new products and protocols such as WME and MeML (Wang, Kajler, Zhou, & Zou, 2003; Wang et al., 2008).

7.4 Limitations of the Study

During the planning, design, implementation, data collection and analyses stages of this study a number of factors emerged as constraints that could potentially affect the process and outcome of this study. These constraints and limitations are discussed in relation to the methodology, design, instruments used and their possible impact on findings.

As discussed in detail in Chapter 3, the methodology of this study was strongly influenced by the design-based research approach and engaged teachers as co-investigators forging strong teacher-researcher collaboration (Hsi, 1998). The involvement of teachers as co-investigators and the involvement of the researcher in the design and implementation of the study poses threats to the credibility of the research due to the potential influence of researcher bias (Johnson & Christensen, 2004). In this study I was closely involved in the design and implementation of the learning environment and worked with other mathematics teachers in implementing classroom use of the online learning environment. This undoubtedly affected and influenced the design and structure of the learning environment, but having a self-awareness and critical reflection on my own dispositions I tried to be inclusive of other teachers' opinions and open minded about being informed by research literature.

In addition, the iteration and partnership aspects of the design-based research allowed this study to have a strong treatment and methodological alignment (Hoadley, 2004). As teachers and co-investigators both Cathy and I were experienced mathematics teachers and had worked in the adult and vocational education sector for a number of years. We were aware of the theories of mathematics learning in the context of adult and vocational education and our design of the learning environment and classroom practice reflected our thinking.

The study was not aiming for generalisability of outcomes as the research method focussed on innovation and intervention at a localised level with a small sample size. So, the results obtained in this study are not generalisable to other contexts, however, as a small scale design and intervention project this study successfully tested and documented conjectures that apply to designing and using online learning environments in mathematics learning more broadly and specifically to vocational contexts.

When a number of students from both the treatment and control groups dropped out of the course we experienced particular difficulties in comparing the two groups in terms of their attitude towards mathematics and achievement scores. This left us with a very small sample size for paired sample tests for comparison thereby reducing the power of statistical reliability of results (refer Chapter 6.5.1). However, available data from a range of sources and methods including interviews, WebCT postings, classroom observation notes and WebCT logs allowed us to triangulate our findings. The collaboration with teachers also allowed for peer review and member check regarding classroom observation and teachers' lesson planning and procedures. The detailed descriptions of practice described in Chapters 4 and 5 enabled me not only to articulate the research perspective from a starting point but also to explain changes in design and strategies occurring during the enactment stage.

The design of the online learning environment has been described in detail in Chapter 4 and its customisation for a WebCT based blended learning environment is covered in Chapter 5. It needs to be acknowledged that the web design of the learning environment was undertaken at a practitioner/ researcher level only and it is possible that a more attractive and refined website could have been prepared with the help of professional instructional designers and programmers. However, the intent of this study was to explore and document how practising teachers in vocational education with their limited training go about bringing changes in their teaching practice. In this context, the design of our web-based learning environment with a collaborative effort of mathematics teachers is able to demonstrate the training and skills issues at a more realistic level.

The online learning environment included interactive resources in mathematics but mostly these resources were sourced from external websites. As designers, the teachers involved in this study did not have any control over the design and content of these external web pages but careful testing and regular updating of links to these external web pages seemed to serve our purpose of navigational scaffolding reasonably well.

In terms of instruments used the attitude towards mathematics was measured using Aiken's Mathematics Attitude Scale but no measure of students' attitude towards computers was undertaken. It seems that students' attitude towards computers also influences their participation in online learning activities (Yushau, 2006) but the issue of students' interest and attitude towards computers was explored informally in interview questions rather than formally using an instrument for measuring computer attitude. However, use of interview data helped in analysing students' attitude towards mathematics and exploring learner readiness factors in using blended online learning (refer Chapter 6.2.1).

7.5 Final Comment

The conduct and writing of this research has been a significant milestone for me personally not only because it introduced me to the intricacies and idiosyncrasies of the research process but because it enabled me and a number of my colleagues to travel on a tangent that led to our professional growth and development. We learned technical skills in design, discovered workings of interactive learning resources on the web and discovered the power of new technologies in understanding and doing mathematics. The research study also revealed to me that technical tools and resources play a less significant role in developing effective teaching practice with technology compared to teachers' beliefs, motivation and working conditions and collecting data and evidence for such findings is very complex and problematic.

The power of web technologies and their impact on workplace practices is rapidly becoming evident to training providers in the VET sector. I think the content and nature of mathematics learning is likely to be transformed with the use of digital technologies all around us. It is important that mathematics teaching in vocational education adapts to these changes to provide young people skills and knowledge relevant for the emerging workplaces.

This research has shown that the Internet offers a unique opportunity to bring about this change in mathematics classrooms. Although a lot of work is still to be done, vocational education mathematics teachers need to be encouraged to adapt new technologies for their classroom practices but before that they would need to have a close look at their assessment practices and align them to new technologies based learning. In vocational education it is even more important to overcome 'the planning paradox' by rethinking our approach to curriculum content and contextualisation of mathematics (Ainley, Pratt, & Hansen, 2006, p. 24). The new technologies and the web offer affordances and real world experiences limited only by the imagination of the teacher.

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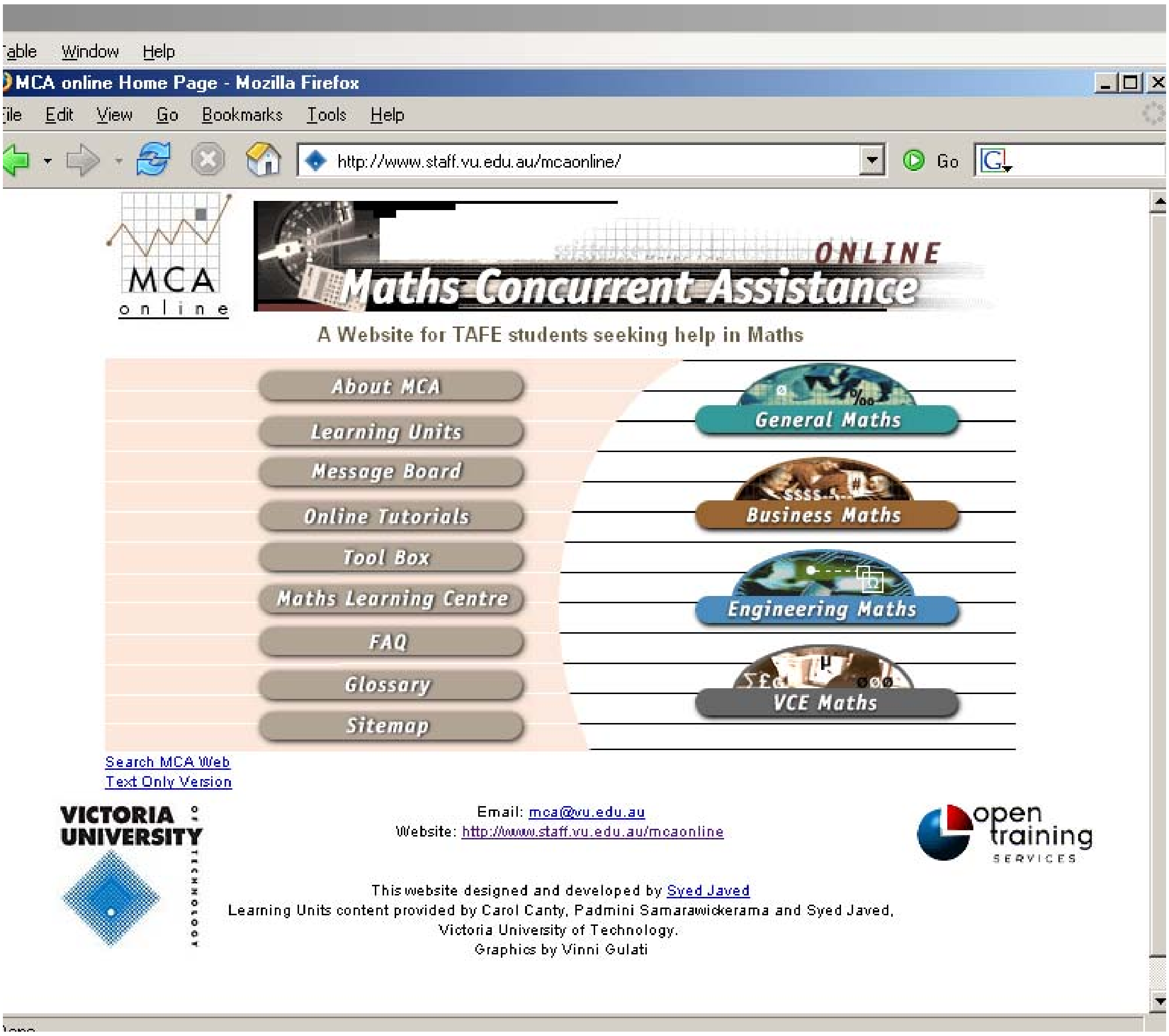
Appendix 1

MCA Online Website

MCA Online Website

Web Address: http://www.staff.vu.edu.au/mcaonline



Appendix 2

Aiken Mathematics Attitude Scale

AIKEN MATHEMATICS ATTITUDE SCALE

Name. ______________________________ **Date:** ______________________

Directions: Circle either YES or NO indicating whether you agree or disagree with each statement

1. I am always under a terrible strain in mathematics class.	YES	NO
2. Mathematics is very interesting to me, and I enjoy mathematics courses.	YES	NO
3. I do not like mathematics, and it scares me to have to take it.	YES	NO
4. Mathematics is fascinating and fun.	YES	NO
5. Mathematics makes me feel secure, and at the same time it is stimulating.	YES	NO
6. My mind goes blank and I am unable to think clearly when working on mathematics.	YES	NO
7. I feel a sense of insecurity when attempting mathematics.	YES	NO
8. Mathematics makes me feel uncomfortable, restless, irritable, and impatient.	YES	NO
9. The feeling that I have toward mathematics is a good feeling.	YES	NO
10. Mathematics makes me feel as though I'm lost in a jungle of numbers and can't find my way out.	YES	NO
11. Mathematics is something which I enjoy a great deal.	YES	NO
12. When I hear the word mathematics, I have a feeling of dislike.	YES	NO
13. I approach mathematics with a feeling of hesitation, resulting from a fear of not being able to do mathematics.	YES	NO
14. I really like mathematics.	YES	NO
15. Mathematics is a course in school which I have always enjoyed studying.	YES	NO
16. It makes me nervous to even think about having to do a mathematics problem.	YES	NO
17. I never liked mathematics, and it is my most dreaded subject.	YES	NO
18. I am happier in mathematics class than in any other class.	YES	NO
19. I feel at ease in mathematics, and I like it very much.	YES	NO
20. I feel a definite positive reaction to mathematics; it's enjoyable.	YES	NO

Appendix 3

Mathematics Achievement Pre-test
(General Mathematics Information Sheet)

General Mathematics Information Sheet

Introduction to Business Maths

Answer all questions. **Time Allowed: 30 minutes**

Use the space provided for working out your answer.

Do not use calculator

Question 1:

0.2 X 0.3 X 0.4 =

Question2 :

Add ½ to ¼ and express the answer as a percentage.

Question 3:

Each month a woman saves $\frac{2}{7}$ of her income and spends \$800. What is her yearly income?

Question 4:

The perimeter of a square is 1 meter. Find its area.

Question 5:

Solve: $-1 \times [-8 \div (-4 + 6)]$

Question 6:

Simplify: $\frac{15 r^7 s^{12}}{30 r^5 s^8}$

Question 7:

A discount of $90 was given on a microwave oven marked at $270. Find

a) the price paid
b) the discount as a percentage of the marked price.

Question 8:

Solve for m:

$$\frac{m+10}{3} = 1$$

Question 9:

For the following set of data find the value of mean, median and mode:

3,2,4,6,8,10,4,20

Question 10:

Find the gradient between A(2,5) and B(4,9) and then find the equation of the straight line.

Appendix 4

Journal Log on Internet Use

Journal Log on Internet Use

Date:	
Your Name:	

NOTE
This journal log is to be completed once every week during the semester of your course - Introduction to Business Mathematics.

1. How many times did you go on the Internet during last seven days?

Your Answer: ____________________

2. Where from did you access the Internet?
[Whether it was from school or home or from a friend's place. Please specify]

Your Answer: ____________________

3. How much time did you spend on the Internet?
[Give rough estimate in hours only]

Your Answer: ____________________

4. What were your main activities on the Internet?
[Give a short account of how you used the internet for educational purposes]

Your Answer:

____

____

____

Appendix 5

Student Interview Guide

Interview Questions for Students

Questions for both Treatment and Control Groups

Q1. Tell me about your reasons for doing this course.

Q2. How do you feel about the content of the course? Is it relevant to you? Do you think you will need to us it in the future? How?

Q3. How much maths have you done in the past? What courses in maths have you taken?

Q4. What is your attitude towards learning maths? Has your attitude changed during this course? How?

Q5. In your view what are the good points about this course?

Q6. In your view what are the bad points about this course?

Q7. Do you bring a calculator to the class? What type of calculator do you have?

Q8. Do you have a computer at home? Is this connected to Internet?

Q9. Do you think that using the computers and Internet can make learning easier for your course? How?

Q10. What kind of maths would you like to do on the computers?

Q11. What do you think about the assessment for this subject? Does it need to be changed? How?

Q12. What was your attendance during this course? Why did you miss any classes?

Q13. Do you contact your classmates after school hours? Do you discuss education?

Q14. How do you prepare for tests and assessment for this subject?

Questions for the Control Group

Q1. Do you think that having access to course information, exercises and assessment would have helped you in this course?

Q2. Would you contact your teacher via email to seek help for solving problems?

Q3. Would you ever consider learning using computers and Internet? If so, under what conditions?

Questions for the Treatment Group

Q1. What contribution do you think the course home page made in your learnig during the course?

Q2. What has been your previous experience in using the computers and the Internet?

Q3. What were the specific areas you used most often on the course home page?

Q4. What aspect of the use of the Internet and course home page was least interesting to you?

Q5. What main issues concerned you about accessing and using the course home page?

Q6. How often did you use the course home page outside classroom and what were your main activities?

Appendix 6

Sample Interview Script (Student)

Student Interview 7 – Juang (Pseudonym)
Tape 3, Side B

Q1. Tell me about your reasons for doing this course?
Well if I had a business, I'd want to travel overseas, yeah, I wanted to be in business and better than being at local I wanted to go overseas, (inaud) the world.

You wanted to travel overseas?
Travel overseas yeah, either tourism or business, so instead of travelling the world I could do business at the same time.

That's your ambition?
Yeah (inaud) and do business at the same time.

Q2. How do you feel about the content of the course? Is it relevant to you? Do you think you will need to use it in the future?
Yeah most of it, maybe import/export is more in the (inaud) trade and the import/export trade, people find it maybe different from what they want to do in the future. It could be relevant to some people who want to be in that sort of section.

So some areas of the course are useful to you.
Yeah.

Examples?
I'm saying everything is relevant but some parts make get a little bit too far in depth, which we may not need in the future.

Q.3 How much maths have you done in the past? What courses in maths have you taken?
Well, all through high school, at VCE I did year 11 and went through Maths methods and I did further methods for year 12 so I'm pretty good at maths.

Your age?
Eighteen.

Q.4 What is your attitude towards learning maths? Has your attitude changed during this course? How?
Yeah, from my view maths is needed everywhere.

So you have a positive attitude?
Yeah, exactly right, got no problem with maths at all.

In this course have you found it more interesting?
Yeah, there's a bit of a mixture, there's mostly all business and (inaud) work, but maths should also fit also in there which is good, gives you a better chance.

Q.5 In your view what are the good points about this course?
Well I get a job out of it at the end, you get good jobs and you can travel overseas.

Of this particular subject?

I find it not too hard which is good cos most of the other ones are brand new to everyone, But maths we've done it through high-school, like we know a bit of it in the background, and also to remind us of how to do maths now.

Q.6 In your view what are the bad points about this course?
We've got the homework, but nothing really bad about it, no points.

Q.7 Do you bring a calculator to the class?
Yes, sometimes I bring my TO83 graphics calculator or I get one of the scientific calculators sometimes.

Q.8 Do you have a computer at home?
Yes.

Is this connected to the internet?
Yes.

How often use it?
5-10 times a week maybe, home and school, a combination of things

Q.9 Do you think that using the computers and internet can make learning easier for your course? How?
Yeah sometimes with research, it's much better doing to do internet, it's a lot easier to access the internet instead of going to the library and go through all the books or go through an encyclopaedia.

And about this subject?
Yeah you can do it …oh if you've got the books here too you go in and yeah, I've done it at home a few times, it's much much better.

Q.10 What kind of maths would you like to do on the computers?
A basic of everything in general really, things that influence business.

Q.12 What do you think about the assessment for this subject?
It's good.

Does it need to be changed?
Not quite sure, it's good, you've got both computer work and writing work as well, you've got a balance of things it's not just writing the whole time, you've got the computer too.

So it's good thing?
Yeah, that's right. Well I'm probably advantaged to some people who don't have computers or the internet at home. But I'm favouring it.

Q.13 What was your attendance during this course? Why did you miss any classes?
I've been attending pretty good, attendance is pretty good for maths class, probably nearly every class, a few times late but should be every class.

Q.14 Do you contact your classmates after school hours?
Yeah I do, not regarding my maths work…maybe at times but my other subjects.

Q.15 How do you prepare for tests and assessment for this subject?
Revise the night before, go through your books, textbooks, well we don't have any textbooks, handouts and notes.

Check the website?
Not as much the website, no

Homepage contribution to your learning?
It's good we did our sums and all, you sort of learn from it as well, and you get the advantages, you get the calculators which makes it easier to sum up all the work. But exercises are good.

Use website see what was done last week, week before?
At times, mostly I do it from home if I actually look.

From home?
Yeah

And useful from that point of view?
Yeah

Previous experience using computers and internet?
Well, it's all been good, I'm in favour of the internet you do a lot of research.

Use email?
Yeah email, I do news and weather and that sort of stuff, research…

Favourite search engine?
Netscape are pretty good, Yahoo's a bit too commercial

You make a Home page of you own?
No.

Specific course homepage areas most used?
(inaud) exercises, and also to give work in, send work to the teacher.

Message board?
Yeah.

Resource page?
Yeah I use that too, it varies (inaud) things.

Main access issues of concern? Problems accessing?
Some people were a bit confused at the beginning of the year with web (inaud serve?), putting www, it wasn't supposed to be like that, some people had problems saying 'I couldn't get in', I said 'oh there's no 'www.'. But now I know what it is so we can…

Access problems from home?
No, not at all. Got in straight away, no problems.

How often use home page outside class?
Depends if there's a lot of work, a lot of the week I'll be there like the weekends trying to send the work to the teacher otherwise no, once every few weeks to see what's happening.

Been happy using homepage?
I have, yeah.

(inaud – I've seen you coasting ---? through…)
Yeah I've done a lot of… posted a lot of assignments (?)

First experience of using internet for your course?
Yeah, at high school it's all different, yeah it's the first time.

If in future, course had homepage like WebCT, could be useful for other subjects?
Could be, yeah. Sometimes…I live far away from here, it's good when you come home and you don't know what's happening, you can have a look you open it up, see what homework you have, you do it on the web, it's as easy as that. Seeing all the handouts, it's all too, it's difficult, you've got a lot of work to see which one's this, but I think through the internet's much better. Good anytime.

You'd like more of this kind of (inaud)?
Yeah, wouldn't mind.

And happy to use?
Yeah cos I've got internet at home, it's much easier for me.

End of interview

Appendix 7

Student Survey: MCA Online Website Project

Your Name:___________________

Course:______________________

Date:________________________

Student Survey

MCA Online Website Project

This questionnaire is to be completed by students who wish to assist in the design and development of an online learning environment to support mathematics learning. Please write your response to following questions:

1. What maths module(s) are you studying this semester?

2. What maths are you having problems with?

   (Give names of topics or examples of questions.),

3. Did you have any problems with your school maths? (If yes, name the topic).

Appendix 8

MCA Online Induction Module

Maths Connexions for Adults (MCA Online)

An Interactive Module based on MCA Online Website

http://www.staff.vu.edu.au/mcaonline

Adult Basic Education
Victoria University- TAFE Division
Melbourne

Maths Connexions for Adults

MCA Online Module

A module based on Math Connexions
for Adults (MCA Online) Website

Developed by
Syed Javed

This module is developed with funding support from the Centre for Education Development and Support, Victoria University.

Produced by the Program of Adult Basic Education within the Department of Adult Literacy and Work Education, Victoria University of Technology TAFE Division.

Content, design and layout by Syed Javed

All enquiries in relation to this module should be addressed to:

The Project Officer
MCA Online Project
Adult Basic Education
Victoria University TAFE Division
Nicholson Street Campus
Footscray 3011

CONTENTS

STUDY GUIDE

Purpose

Welcome to MCA Online Module. This module is designed to help you acquire the skills and knowledge of learning maths using MCA online website. The module aims to familiarise you with a range of online resources helpful in practicing and solving maths problems.

This module aims to develop learning to learn and problem solving skills in maths by making use of online maths resources. The activities in the module have been designed to reinforce and complement classroom based learning. If learners would like some support for the completion of the activities, they are encouraged to contact their tutor via phone, email or message board facilities.

Duration

This module nominally requires 18 hours for completion of learning outcomes. The actual time may be more or less as the duration will depend on individual experiences, prior knowledge and access to online facilities. You will be expected to attend 4 hours of training and induction sessions in a computer lab. You can complete learning activities and assessment tasks in a flexible time frame in negotiation with your tutors.

Prerequisite

You are expected to have some prior knowledge of using computers and the Internet. You are also expected to be an enrolled student within the TAFE Division of Victoria University.

During the module you will be using MCA Online website which requires Netscape Naviagtor 3.0 or Internet Explorer 3.0 or later version of Internet browsers. Most Victoria University computers now have Netscape Navigator installed on them.

How to use this module

This module is divided into four sections. Each section covers one learning outcome. Each learning outcome has a number of learning activities. Completing these learning activities will help you achieve the learning outcome for that section.

At the end of each section there is an assessment task. You will need to complete these assessment tasks to demonstrate your competence for each learning outcome.

Learning Outcomes

The module aims to achieve four learning outcomes listed below. In order to achieve these learning outcomes you will be introduced to a number of learning activities within each section. The learning activities are:

Learning Outcome 1:
Communicate using MCA Online Message Board

In this section learning activities will include:

1. Register with MCA online message board
2. Post a new message
3. Locate, read and reply to a posted message
4. Participate in real time tutorial

Learning Outcome 2:
Identify appropriate paths for solving problems at MCA Online

In this section learning activities will include:

1. Follow a learning unit to understand basic maths concepts
2. Solve new problems using webmath links
3. Locate Dr Math responses to solve maths problems

Learning Outcome 3:
Find and use relevant maths tools and resources

In this section learning activities will include:

1. Find maths terms in online glossaries
2. Convert units using online calculators
3. Operate an online scientific calculator

Learning Outcome 4:
Become familiar with online maths symbols and expressions

In this section learning activities will include:

1. Locate and use maths symbols and formulae
2. Solve problems using online links
3. Solve interactive puzzles

Assessment Guidelines

Assessment for the module is based on negotiated outcomes between the tutor and student. You are expected to demonstrate satisfactory achievement of learning outcomes covered by this module.

You will be presented with assessment tasks at the end of each section. Complete these tasks and return them to your tutor.

Alternative tasks can be negotiated with your tutor to demonstrate satisfactory achievement of competence.

Contacting Your Tutor

Your MCA Online module tutor is available via phone and email to answer your questions and concerns even after in-class sessions. You can send up to 3 email queries per week to your tutor. In most cases your tutor will answer your email within 24 hours.

When sending an email message to your tutor please type "mca online" in the subject heading of your email.

You can also contact your tutor and other MCA Online users by posting a message on MCA Message Board. When you post a message on Message Board it can be read by all users and any of the registered users can reply to your message.

Phone: 03-9284 8873
Email: syedjaved@vu.edu.au

SECTION 1: Communicating Online

When you have completed this section, you should be able to perform and demonstrate the following learning outcome in accordance with the assessment criteria and conditions listed below.

Learning Outcome:

Communicate using MCA Online Message Board and Live Chat facility.

Assessment Criteria:

- Register with MCA Online Message Board to obtain unique login details.
- Post a new message in a selected conference folder on the Message Board
- Locate, read and reply to a posted message
- Join Live Chat facility on MCA Online and participate in real time tutorial

Conditions:

Access to an environment conducive to computer assisted learning.

During learning and assessment activities students will have access to MCA Online Website.

SECTION 1: Communicating Online

Using MCA online you can get in touch with other students and teachers in two ways:

1. By using MCA Message Board you can post your own messages for others and read other peoples messages and responses

2. By using MCA Online Chat you can join live chat sessions and talk to fellow students and teachers using Online chat.

Using MCA Message Board

Logging in as a Guest

You can use the Message Board easily once you arrive at MCA Online website. There are two ways to enter MCA Message Board. If you just want to browse the conferences without posting your own messages or participating in chat, you should log in as a guest. To do so, click Guest on the login page.

The main message board page appears with the Conferences list and a welcome message. Click on the + sign next to a conference to expand it and then click on a message heading to open it for reading.

Tip

Sometimes after logging you as a guest, MCA Message Board may not allow you to log in as a registered user. In this situation it will not show you the login window. What you need to do is exit your browser and restart your Netscape program. Come to MCA Message Board page and click on login as a user link.

Logging in as a New User

If you want to participate in Message Board either by posting messages or chatting, you must be a registered user and have your own Message Board Account. You can self-register and create your own account instantly by selecting a login name and password and providing some additional information such as your real name and email address. You should choose a login name and password that is easy for you to remember (note this down in your diary for future reference). If you do not have an email address type MCA Online email address in this field - mca@vu.edu.au

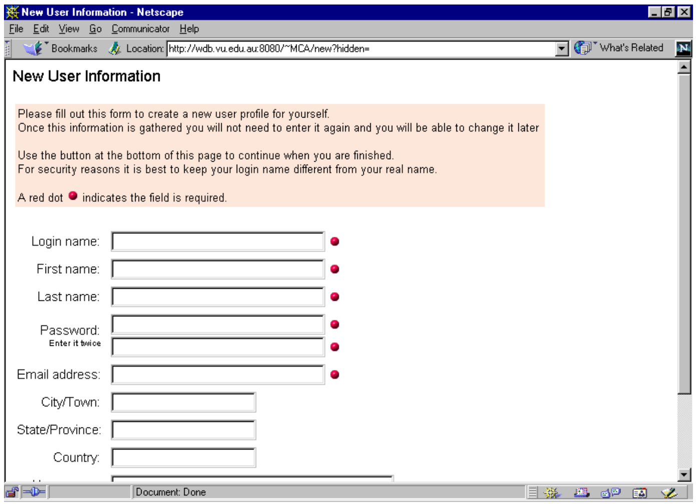
Tip

When selecting your login name and password, keep in mind the following:

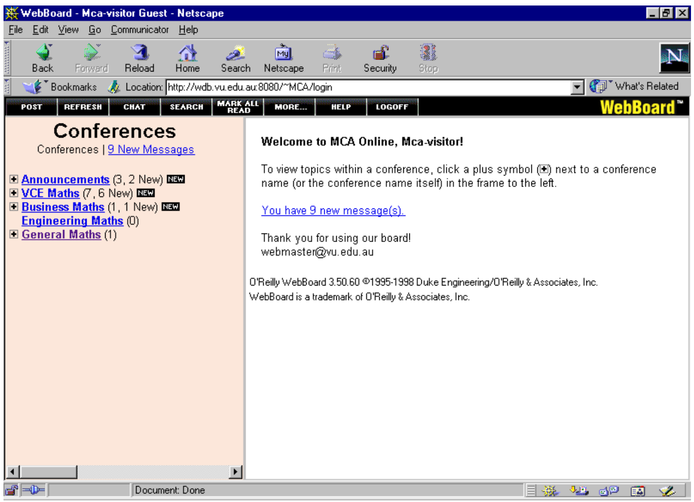
- your login name and real name should be different
- your password should be different from your login name and you should keep it secure
- your login name must be unique so you may be asked to use a different login name.

Activity 1.1:
Registering as a new user with MCA Online Message Board

This activity will help you create an account with MCA Online message board. Once you have created an account for yourself, you can go to Message Board directly and participate by reading and posting messages. Follow these steps:



1. Open MCA Online Home Page by typing www.staff.vu.edu.au/mcaonline in your browser goto field and press Enter.
2. Click on Message Board button on MCA Online Home Page
3. Click on the Registration Form link. The New User Information form appears
4. Follow the directions on this page and fill in the required blanks (marked with red dots). If you do not have an email address type mca@vu.edu.au in the Email Address field.
5. You may leave the city, state, country and home page fields blank.



6. Choose Yes for Use Frames option.
7. Click on Create button to finish the registration process. If your login name is unique, WebBoard creates the account and displays the main WebBoard page. If your login name was already being used or some other information was missing, you must complete the form again and resubmit it.
8. Note down your login name and password in your diary for future use.

Working with the Message Board

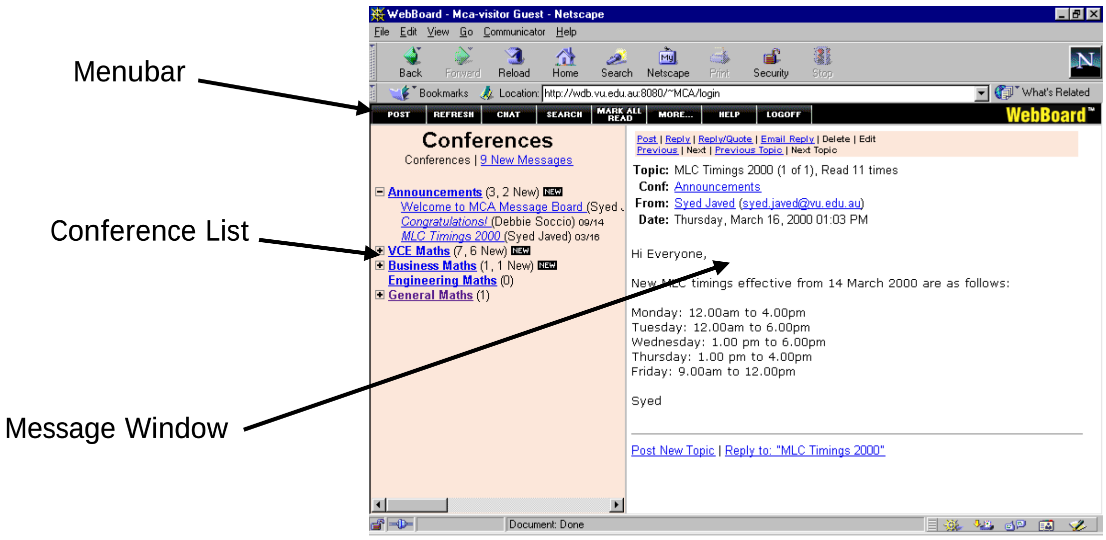
Before you start posting messages and participating in chat sessions, you'll want to take a few minutes to become familiar with Message Board's layout and basic operation, including navigation and functionality. Once you've successfully logged in, either as an existing user, new user, or guest, you will see the board's main page, where most Message Board activity occurs.

Typically, a board's main page has three main activity areas, which are listed below:

- **The conference list** (left frame) displays the conferences, topics, and messages. Here you will see conferences such as Announcements, VCE Maths, Business Maths, Engineering and General Maths. A + sign next to the conference name suggests that there are messages within that conference. You can click on the + sign to view a list of messages.

- **The menubar** (top frame) has buttons for using Message Board's commands and features.

- **The message window** (right frame) is the working area where information and forms are displayed. For example, the message window is where you read and post messages, complete user profile information, and execute searches.



Browsing Conferences, Topics, and Messages

Before you start posting messages, take a few minutes to browse through the conferences, just as you would browse through several books before selecting one for complete reading. Looking through the conferences, topics, and messages gives you a good idea of what information is on this board, as well as how others are presenting information.

The Conferences list shows all the conferences on this board. An expansion box (+ icon) to the left of a conference name indicates that the conference has topics and messages. The numbers in parentheses to the right of the conference name tells how many total and how many new messages are in it. Conferences with new messages have a NEW icon to the right of the conference name.

To display the topics in a conference, click the conference name or the expansion box. You can expand one conference at time. When you expand another conference, the previous topic list collapses. Or, you can close the conference list by clicking the expansion box again

An expansion box to the left of the topic name indicates that this topic contains more than one message. Topics and messages both have hyperlinks that you can click to open them in the right frame. To the right of each topic and message is the poster's name and date. The poster's name is also a hyperlink to that person's profile.

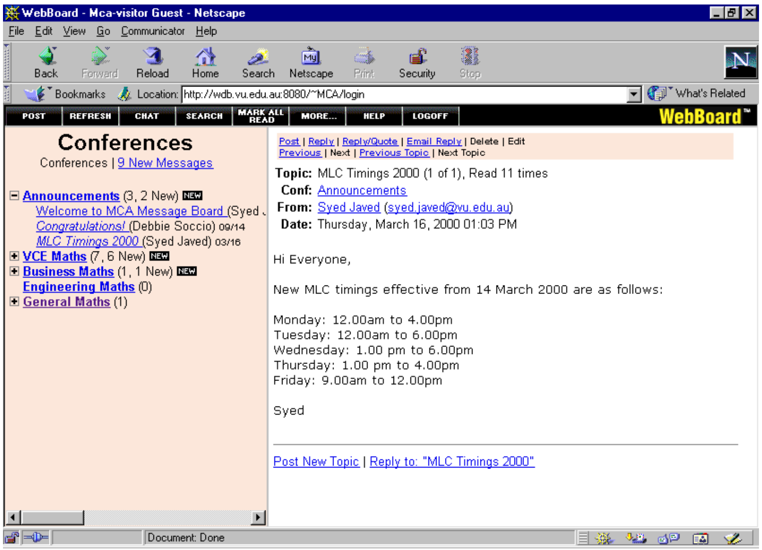
Tip

You can get an email notification of messages posted on this Message Board. Simply login to Message Board and choose More menu from the toolbar. Click on Email notify and place a tick on conferences you wish to receive email notification. Choose Save.

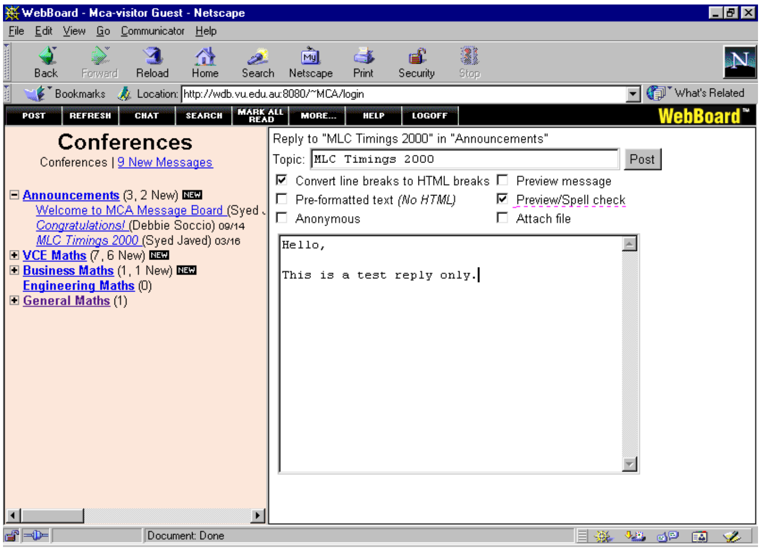
From now on any messages posted on selected conferences will be automatically forwarded to your email address.

Activity 1.2:
Reading a Message and Replying

In this activity you will open and read a message posted in the Announcement conference.



1. Log on to MCA Message Board. You will need to use your User Name and Password for the account you created in Activity 1.
2. From the Conferences list, click on the Announcement conference or click the expansion box (+ icon) next to it.
3. Locate the topic MLC Timings and click on its name. The message and replies are displayed in the message window.
4. The message displays in the Message window. You may need to scroll to read the entire message(s).



5. Click on the link 'Reply to MLC Timings' at the bottom of the message window. A new form will open in place of message.
6. Type a short reply in this window. You may tell us about what timings suit you most to visit the MLC at Footscray campus.
7. Click on the Post button next to topic heading at the top of the message. This will take you to a preview window, just in case you needed to change anything.
8. Click Post button to send your reply on message board.

Activity 1.3:

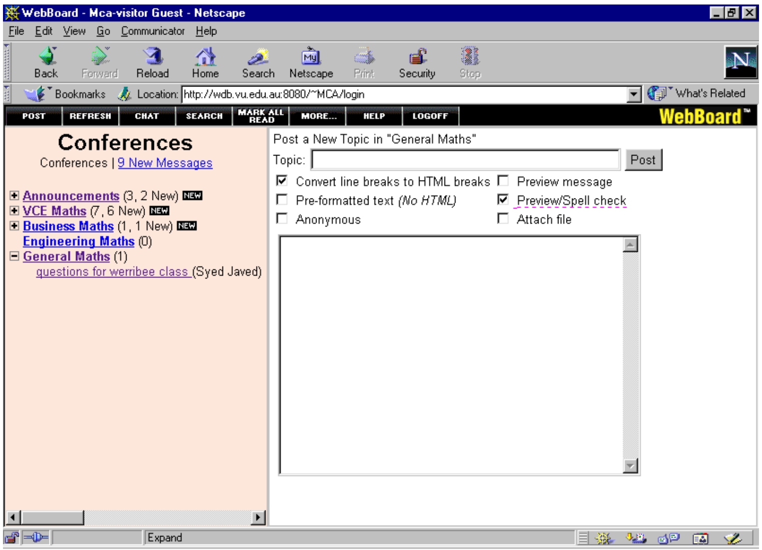
Post a new topic message on the message board

When you post to a conference, you are either adding to a current topic or starting a new topic. If you have something new to contribute or ask such as a comment or a question then you can start a new topic. If you are replying to someone's question or posting then you do not need to start a new topic. You simply open the message and choose reply to message option. The following activity describes how to post a new topic message.

1. Log on to MCA Message Board. You will need to use your User Name and Password from the account you created in Activity 1

2. Select a conference by clicking the conference name or expansion box (+ to the left of the conference name).

3. Click on Post button from the Message Board menubar



4. Enter the new topic name in the Topic field. Keep the topic name short. It should give a clear idea of what message is about - e.g. help needed with algebra, how to use MCA chat, where can I find VCE questions? Etc

5. Type in your message. When you complete your message, click Post. Depending on which options you have selected, Message Board either posts your message immediately or allows you to preview it (with or without spell checking)

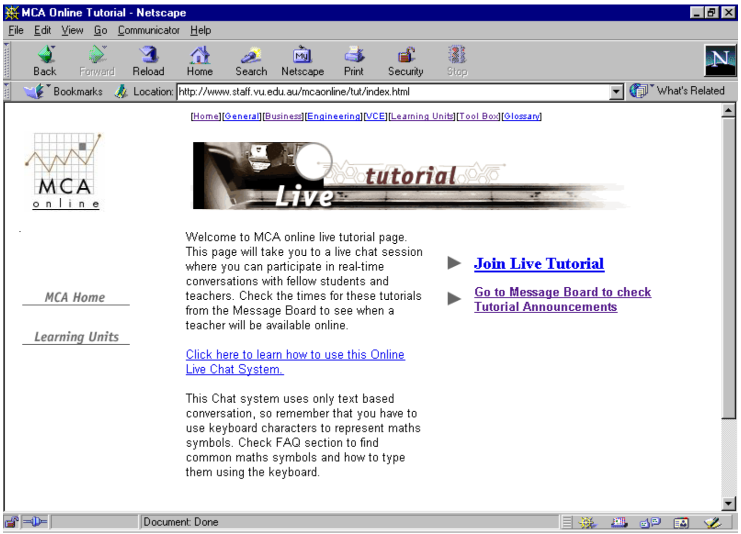
6. Preview the message for any spelling errors and after correcting click on Post button.

Logging Off

When you are finished with your Message Board session, you can simply point your browser at another site on the Web or you can officially log off Message Board. The Logoff button in the menubar takes you to MCA Online Home Page. If you wish to come back to Message Board, simply click on Log in a User button from message board page. You will be taken directly to the Message Board. The browser remembers your user id and password.

MCA Online Live Tutorial and Chat

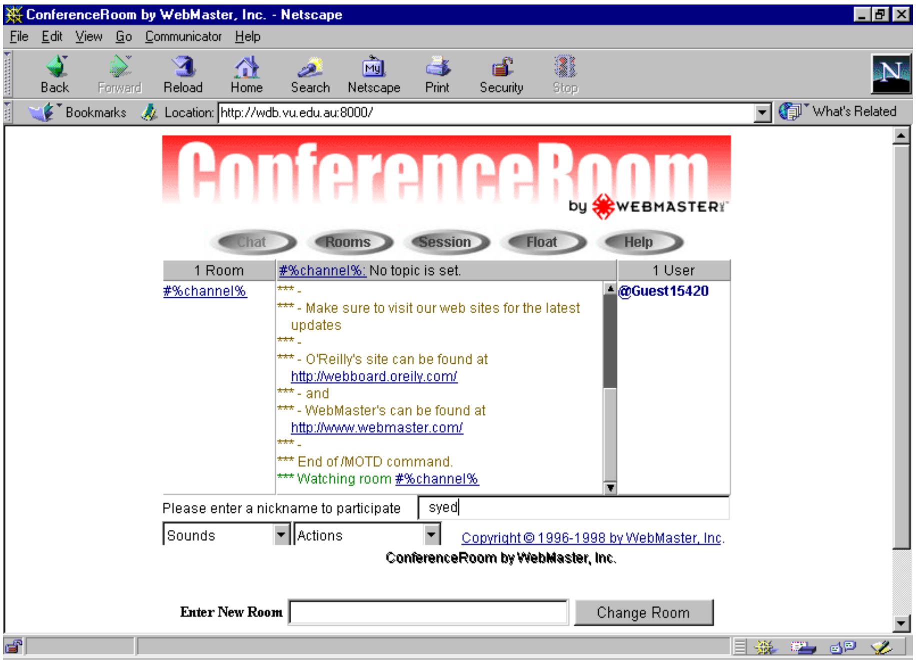
The MCA online Live Tutorial facility offers teachers and students to interact in real time using a Java based conferencing client. This conference uses only text-based chat. It is similar to many Internet based chat systems such as YAHOO chat and MSN chat. You will need to find out chat times from Live Tutorials page to know what is the best time to log in to chat session.



Some useful tips for participating in online tutorials sessions are given here. Follow these tips to make best use of online chat sessions:

- In online chats you need some practice on your keyboard so that you can type your sentences quickly. Become familiar with the keyboard and improve your typing speed.
- Use abbreviations and shortcuts to say most common phrases.
- Type your commonly used phrases and questions in a program such as Notepad or Word before joining chat session. Keep your Word file open while chatting. Copy and paste blocks of text from word file to online chat window as needed.

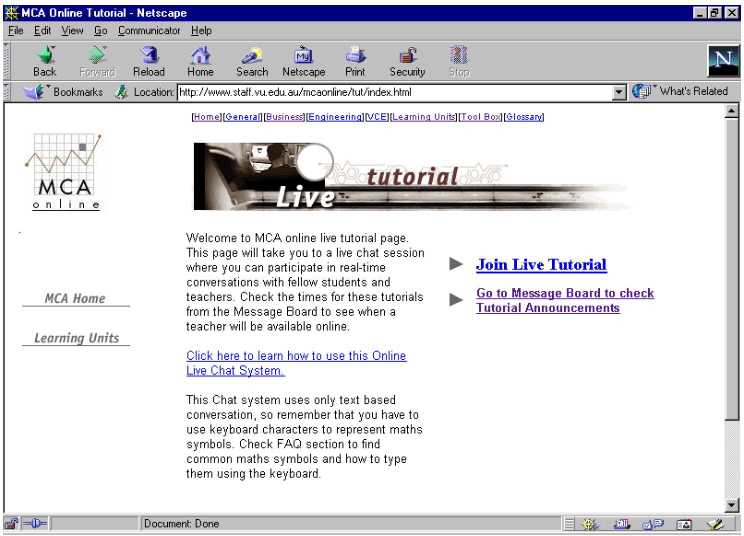
In using the Conference Room you can create new rooms and have multiple chat windows open for different rooms. Type a name such as 'private' in the enter new room field and click on the button change room. You will now be talking in this new 'private' room. If you wish to move to another room, double click on the room's name in the chat window. A new window will open up for your chat session. In this way the program allows you to create new rooms and chat with different people without being distracted by others. But, for the purposes of MCA chat sessions on maths we will be using only one chat window.



Activity 1.4:

Join and participate in an online live tutorial

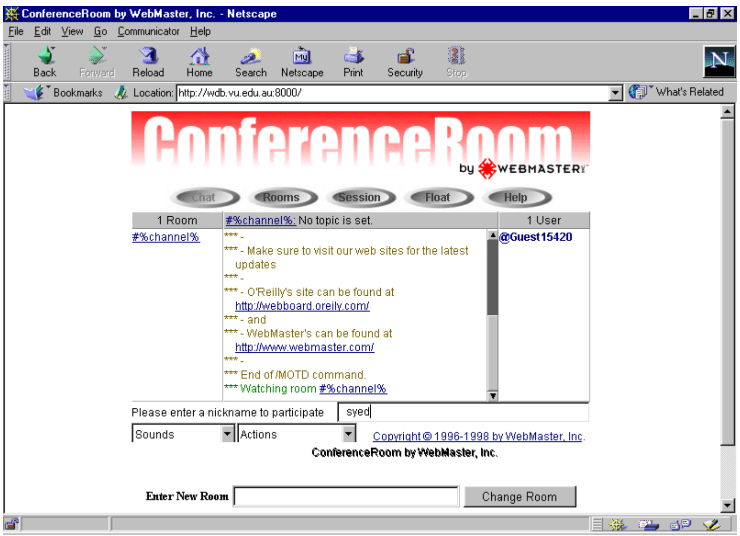
In this activity you will take part in a live chat session at MCA website. If you are doing this activity on your own please check live chat times to know when next chat session is scheduled. You can check these times by visiting Live Tutorials page or by going to Message Board and checking online chat announcements. If you come to chat at other times there may not be anyone else to chat with.



1. Open MCA Online website and click on Online Tutorials link. This link will take you to Live Tutorials page.

2. Click Join Live Tutorial link to open a chat conference room. The Conference Room for chat will open in a new browser window in a few seconds. Your browser must be Java capable for this chat feature to work. You must have Netscape or Internet Explorer version 4.0 or above for this chat facility to work properly on your computer.

3. Type your first name in the text field next to the words, 'Please enter a nickname to participate' and press Enter key. This will make your name appear in the user column.



4. Type your message in the text entry field and press enter key. Your message will be posted on the chat window.

5. Continue your discussion and use Actions and Sounds prompts from pull down menu located just under the text entry field.

Assessment Task 1

This assessment task is based on your understanding and knowledge from Section 1 of this module. Your tutor will give actual date and time for completing this assessment task to you.

Task 1a

Visit MCA Online message board and read the problem posted for your group in Assessment Conference folder. Your task is to follow instructions to solve the problem and complete the task. After you have completed the task, log in to MCA Online Message Board and post your answer in the Answer Box Conference folder.

In order to complete this task you may need to use MCA online resources from Toolbox and Learning Units sections.

Task 1b

Visit MCA Online Message Board and read the messages posted in Tutorial Times conference folder. Find the timings for the next online tutorial session by reading recently posted messages.

Your task is to join in and participate in online chat at the specified time. In order to complete this task you may need to go over Activity 4 from Section 1.

SECTION 2: Working with Maths Problems

When you have completed this section, you should be able to perform and demonstrate the following learning outcome in accordance with the assessment criteria and conditions listed below.

Learning Outcome:

Identify appropriate paths for solving problems at MCA Online

Assessment Criteria:

4. Follow a learning unit to understand basic maths concepts
5. Solve new problems using webmath links
6. Locate Dr Math responses to solve maths problems

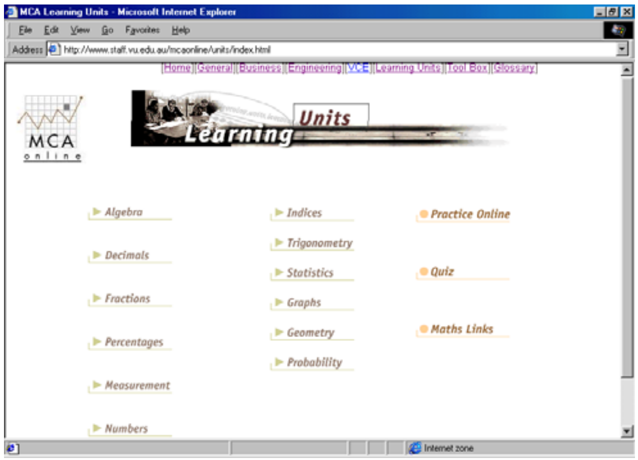
Conditions:

Access to an environment conducive to computer assisted learning.

During learning and assessment activities students will have access to MCA Online Website.

SECTION 2: Working with Maths Problems

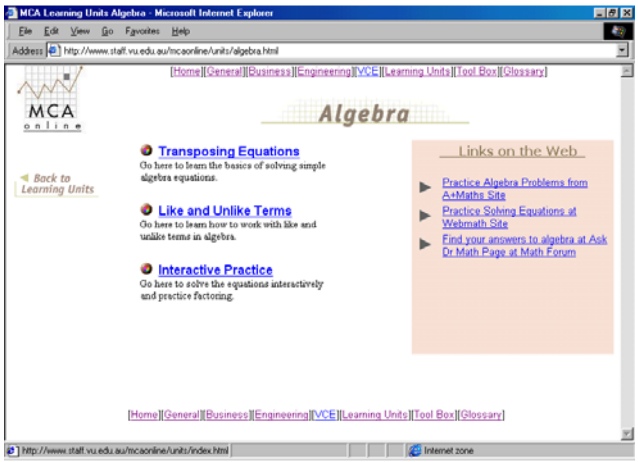
To work with maths problems at MCA Online you will need to go to the Learning Units section. The Learning Units section gives you direct access to simple explanations and examples on common maths topics. The difficulty level of maths topic is maintained at pre VCE range. The topics covered in this section include algebra, decimals, fractions, numbers, measurement, indices, percentages, geometry, trigonometry, statistics, graphs and probability.



You may choose to follow a particular learning unit such as Algebra in more detail. You can access individual maths unit from a number of pages but the quickest way to get to your selection is via the Learning Units page.

Learning Units

Each learning unit is comprised of two or more sub-units and provides access to relevant websites on that topic for further practice and exploration. If you are visiting Algebra unit, you will notice that it offers you access to Transposing Equations, Like and Unlike Terms and Interactive Practice sub-units. It also provides access to practice links from other websites.



In any learning sub-unit section you will find the actual topic description and tips on how to solve problems based on that topic. For example, when you visit Algebra learning unit, you can choose to go to Transposing Equations sub-unit. In this section you will find a simple technique of transposing equations explained clearly. You should click on Examples, Practice Questions and Have a Go links to explore the topic in more detail and try some questions.

Links on the Web

From each learning unit's page, MCA online provides links to websites offering more learning activities on the topic. These learning activities come from the following sources:

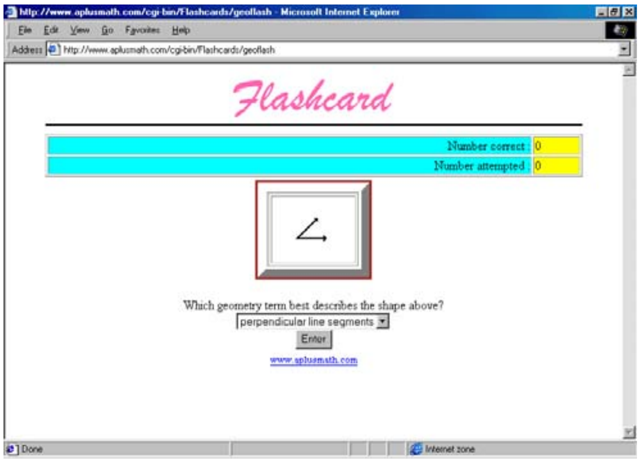
Webmath

Activities offered via this link are interactive and you are able to solve your maths problem by entering it in the required format. Webmath solves your problem in a detailed step-by-step method. Sometime these steps may appear repetitive and unnecessary. Being an automated program Webmath is not as intelligent as a real teacher, but gives correct solutions. When entering your own problems at Webmath pages you must stick to the format suggested by Webmath. Have a look at the examples suggested by Webmath and use the following hints when typing your problems:

- The ^ symbol means exponent. So, for example, *x^2* means x^2, *5^2* means 5^2 and *3.2^2* means 3.2^2.
- + means plus, - means minus, / means divide, * means multiply
- In most cases, you don't need to type the *, Webmath automatically knows when to multiply
- Any keyboard letter may be used as a variable, like *x*, *y*, *z*, *a*, *b*, etc.
- You may use grouping symbols, like (and), [and], or { and }.

A+ Math

Activities offered via A+ Math links are interactive practice exercises. In these activities maths problems are presented to you and you have to select or type the correct response for the problem. In some topics you will need to select the type of problems you need to practice before going on to practice flashcards and doing the problems. Each problem is corrected by the program and your score is displayed in a score window. Note that A+Maths activities do not have the option to type your own problems.



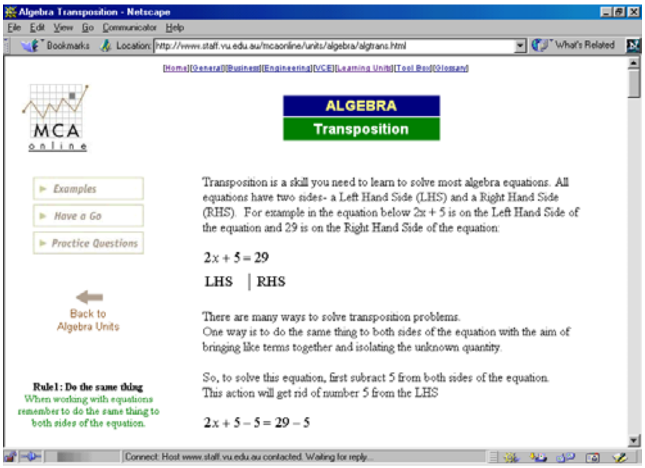
Ask Dr Math

This link provides direct access to past questions and answers by expert maths teachers from Ask Dr Math website. There is a long list of questions and answers on each topic and you will need to scroll down this page to see more questions. The topics are arranged according to grade levels. Most questions and answers archived on this website are based on real problems posted by students around the world. It is recommended that you spend some time browsing through the questions and answers on selected maths topics. It helps to develop your awareness on concepts related to that topic.

The activities on following pages are aimed at increasing your skills and knowledge in solving maths problems using Learning Units section.

Activity 2.1:
Follow a Learning Unit to revise basic concepts of Algebra Transposition

In this activity you will go through a learning unit on algebra transposition to revise your maths concepts and to become familiar with learning unit path on MCA online. The steps shown in this activity are generic and can be used on other learning units as well.



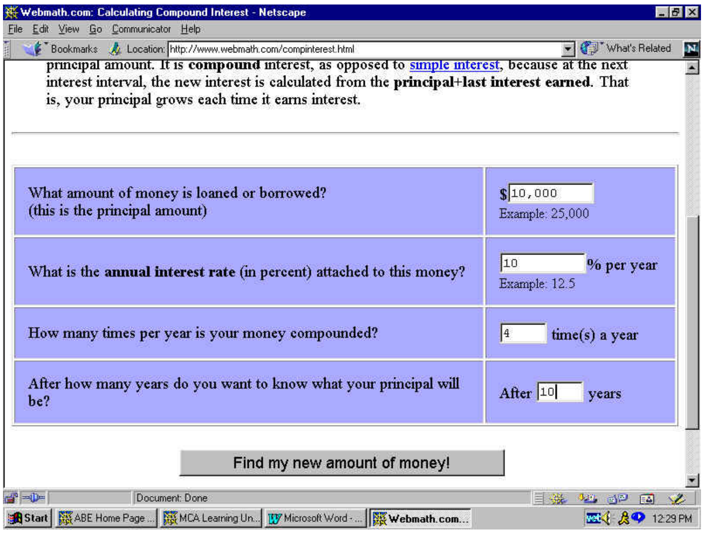
1. Go to Learning Units sections of the MCA Online website.
2. Click once on Algebra hotlink to go to algebra learning units page
3. Click on Transposing Equations link to go to the subunit - Algebra-Transpostion
4. Read the introduction section. Scroll down if necessary.
5. Click on Return to Top hotlink to go back to top of the page.
6. Go to Examples section by clicking on Examples hotlink at the left margin of the page. Follow the examples and click on Return to Top hotlink to get back to top of the page
7. Click on Have a Go hotlink at the left margin of the page to go to Have a Go section. Try solving the problems. You may use a pen and paper at this stage, if needed.
8. Click on See Solution hotlink to go to solutions of these problems and compare your working with the one on MCA Online. Click on Return to Top hotlink to go back to the top of the page.
9. Go to Practice Questions section by clicking on the Practice Questions hotlink at the left margin of the page.
10. Attempt practice questions. Use pen and paper, if necessary.
11. Click on the drop down button at the Answer hotlink. You will see correct answer displayed in the Answer box.
12. Go back to top and click on Return to Algebra Units hotlink at the left margin of the page. You are back the Algebra units home page.

Activity 2.2:
Solve Maths Problems Using MCA Online links on the web

In this activity you will use an interactive Webmath page to enter your maths problem on compound interest and see how it can be solved. The Webmath will actually solve the problem and show you the working out. The problem you are asked to solve is as follows:

A $10,000 investment attracts interest of 10% p.a. compounded quarterly over a 10-year period. How much interest will have accrued at the end of that period?

Follow these steps to see how this problem can be solved:



1. Go to Learning Units sections of the MCA Online website.

2. Click once on Percentages hotlink to go to Percentages learning unit page.

3. On Percentages page click on Compound Interest Problems hotlink from Links on the Web section. The Webmath's Calculating Compound Interest page will open in a new browser window.

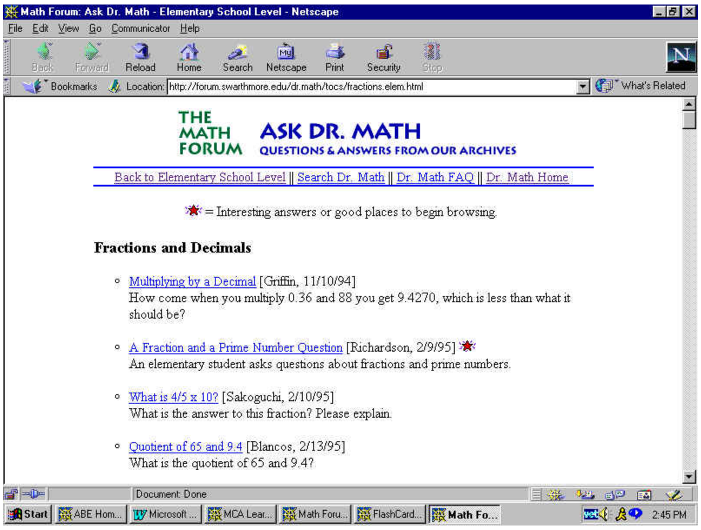
4. Scroll down to view compound interest data entry fields for principal amount, interest rate, compounding period and number of years.

5. Enter your data from question above in correct data fields and press Find my new amount of money button.

6. The program solves your problem and returns a page with complete solution. Scroll down this page to view the complete solution. The problem is solved in a step-by-step method to give you an understanding of the method and then at the end the formulae for solving compound interest problems is used to show that both methods provide same results.

Activity 2.3:
Search and find solutions from Ask Dr Math archives

In this activity you will visit Ask Dr Math questions and answers archive. This website has an extensive collection of maths questions and answers categories topically. In this activity your task is find an explanation for the process of dividing fractions.



1. Go to Learning Units section of the MCA Online website.

2. Click on Decimals hotlink to go the Decimals learning unit page.

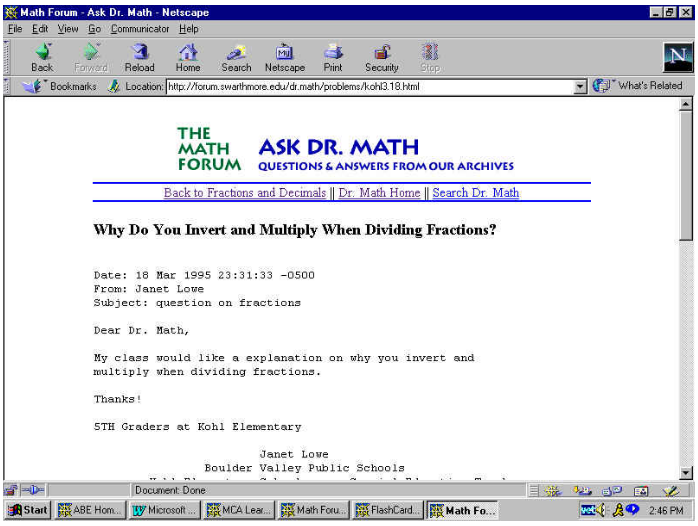
3. On Decimals page click on Ask Dr Math about Decimals hotlink listed under Links on the Web heaading. Ask Dr Math page on the topic of decimals will open in a new browser window.

4. Browse through the listed topics to find questions relating to dividing fractions.

5. Click on underlined topic name to open the question and answer page. This page opens similar to an email text.

6. Read a number of replies related to the problem of dividing fractions.

7. Think of a question similar to one posted on Ask Dr Math pages and post it on MCA message board.



Assessment Task 2

This assessment task is based on your understanding and knowledge from Section 2 of this module. Your tutor will provide the actual date and time for completing this assessment task to you.

In this task you will use your maths knowledge and resources available in Learning Units section of MCA Online to answer questions given to you by your tutor. The Questions Sheet contains 10 maths problems. Answer all questions using MCA online pages where appropriate and submit your answers on an answer sheet to your tutor.

SECTION 3: Using Tools and Resources

When you have completed this section, you should be able to perform and demonstrate the following learning outcome in accordance with the assessment criteria and conditions listed below.

Learning Outcome:

Locate and use online maths tools and resources

Assessment Criteria:

7. Find Maths terms in online glossaries
8. Convert measurement units using online calculators
9. Operate an online scientific calculator

Conditions:

Access to an environment conducive to computer assisted learning.

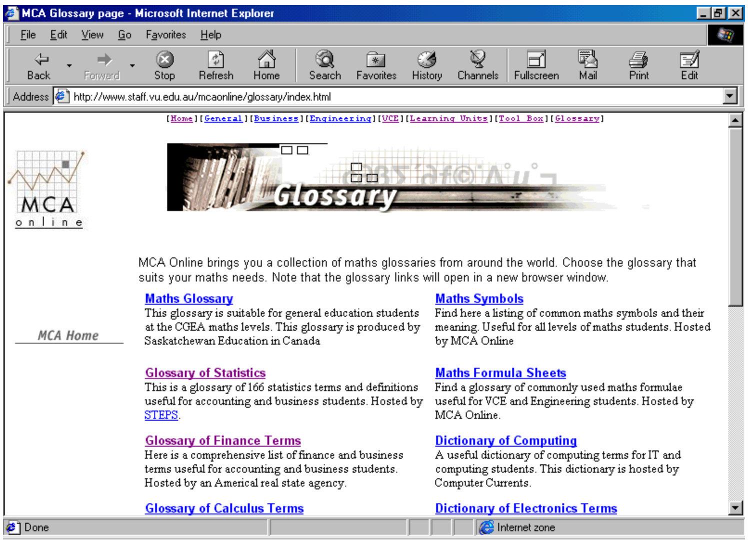
During learning and assessme0nt activities students will have access to MCA Online Websit0e.

SECTION 3: Using Tools and Resources

While working with maths problems many times you need to use special maths tools and resources to help solve the problem. MCA online makes a number of very useful tools and resources available to you via the web. You can access an online scientific calculator, use conversion tables to change several imperial and metric units of measurement, look up difficult maths terms in a glossary of terms or access symbols and formula pages to look up symbols and formula cheat sheets.

You should note that these maths tools and resources are there to help you solve real maths problems. So, when you read a maths problem and find a maths word that doesn't make sense to you, it is a good idea to look up the glossary of terms and find the meaning of that term. Similarly, while working on problems using indices if you don't know how the index law will apply in this particular case, go upto Formula sheets in Toolbox and have a quick look at the index laws summary. Now let us look at these maths online tools and resources closely.

Glossary of Terms

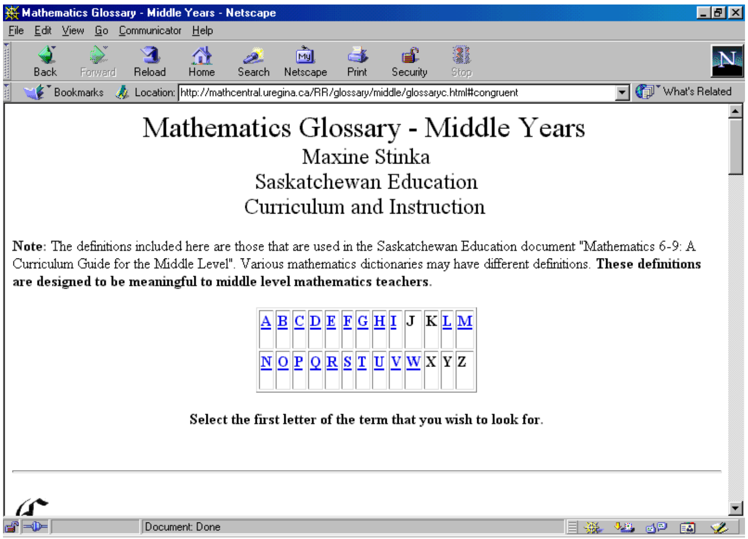


There are several online glossaries for maths that help you to find the meaning of commonly used maths words. The Glossary page from MCA Online provides links to these glossaries. When you open a glossary page you will see an alphabetical index of listed words. The letters A to Z are hypertext links. Click on the letter that begins your word and you will be presented with terms beginning with that letter. If necessary, scroll down the page to find your word. If your word is not listed in this glossary try another glossary from the Glossary page. It is like using a dictionary, you may have to look at several glossaries to find meaning of some specialised terms. MCA online provides links to some specialised glossaries for Finance, Statistics, Calculus and Computing terms. Try these for technical terms from specialised fields. Note that each glossary opens in a new browser window and you can return to MCA Online Glossary page by choosing it from the task bar at the bottom of your monitor screen.

Activity 3.1:
Find Maths terms in online glossaries

In this activity you will use online glossaries to find meanings of following maths terms:

a. congruent
b. histogram

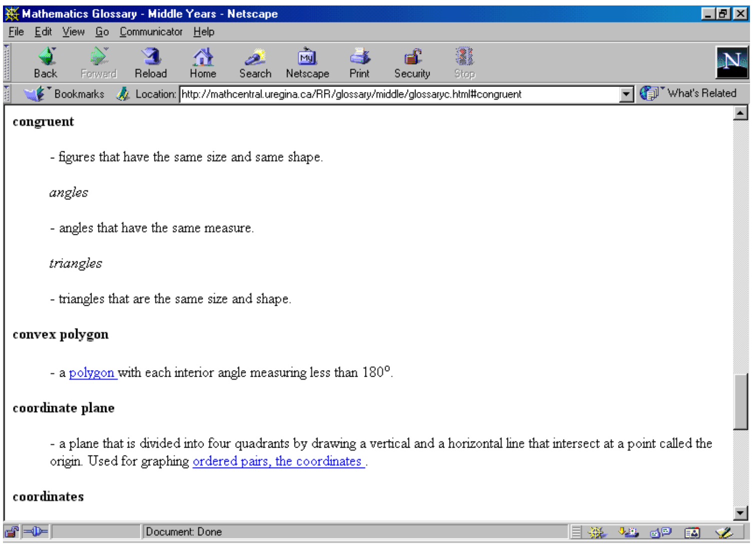


1. Go to Glossary section of the MCA Online website.

2. Click on Maths Glossary link on this page. This will open Mathematics Glossary-Middle Years in a new browser window.

3. Click on letter C to move your page to the section where the term congruent should be listed.

4. Scroll down to see more listings under C until you find Congruent. Read the meaning and note it down in your notebook.

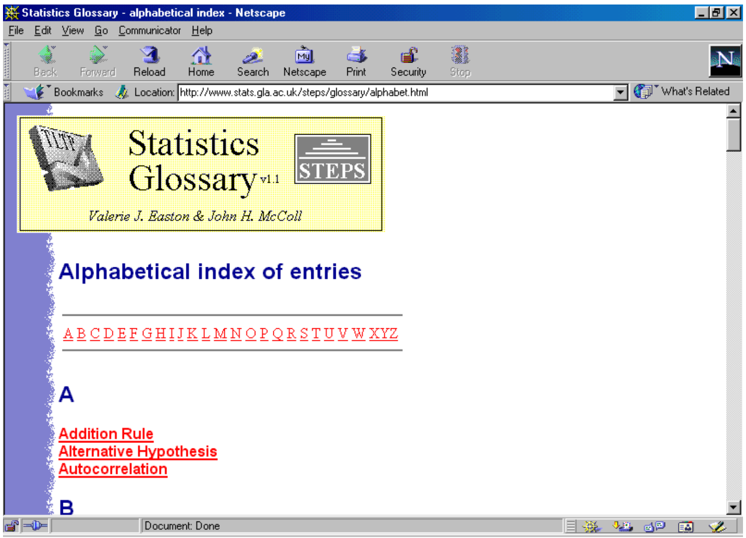


5. Scroll back to top of the page and click on letter H to go to the section where Histogram should be listed.

6. Scroll down to see more listings under H until you find Histogram. Read the meaning and note it down in your notebook.

The term Histogram comes from Statistics, now we will look up the meaning of this term in the Statistics glossary.

7. Close the browser window for Mathematics Glossary- Middle Years and return to MCA Online Glossary page.



8. Click on Statistics Glossary link. This will open Statistics Glossary Page in a new browser window.

9. Click on letter H to move to the section listing words under H.

10. Find the word Histogram and click on it. You will see a page with Presentation terms used in Statistics.

11. Scroll down this page to find Histogram and click on the word.

12. A detailed explanation of the term Histogram is presented. This is a more detailed meaning of the term Histogram with illustrations.

13. Close the browser window after reading. This will return you to MCA Online Glossary page.

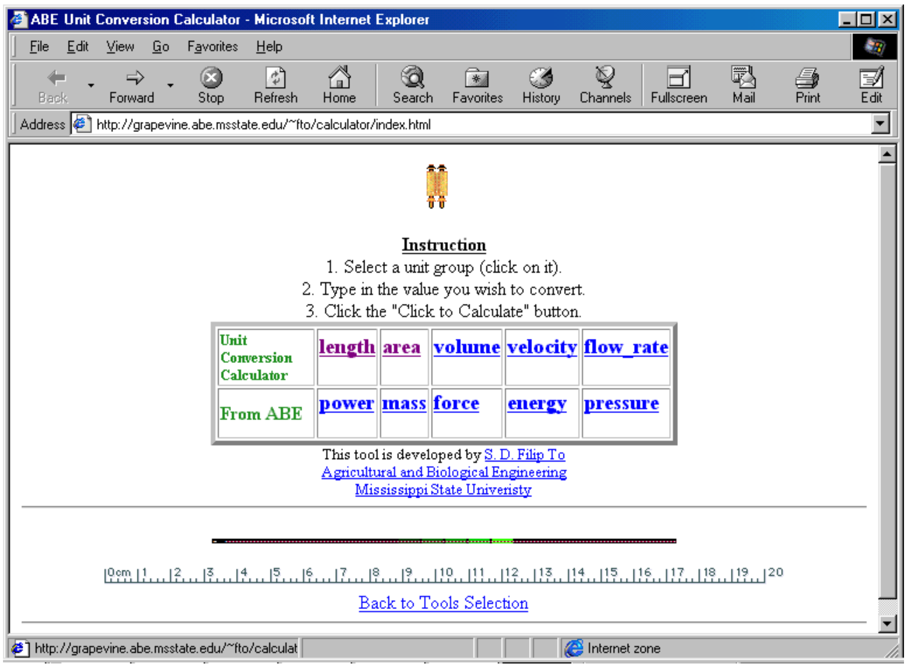
Extension Activity

Using Online Glossaries find the meaning of following maths terms:

Annuity, Box Plot, Vertex, Polynomial and Median.

Units Conversion

The units conversion tools accessible from MCA Online can be used to convert measurement units. These calculators are available from Tool box section and offer conversion calculators for length, area, volume, mass, power, force, energy, velocity, flow rate and pressure. A separate Volume Calculator page offers volume calculation for shapes such cylinders, cones, spheres, pyramids and boxes.



The online calculators use javascript programming to give you instant results. The unit conversion window shows large numbers in a special scientific notation. For example 5000 will be shown as 0.05e+6 meaning the same as 0.05×10^6. You will need to use your knowledge of scientific notations to convert some of the results into natural numbers.

Note that there are differences in British and American unit measurements.

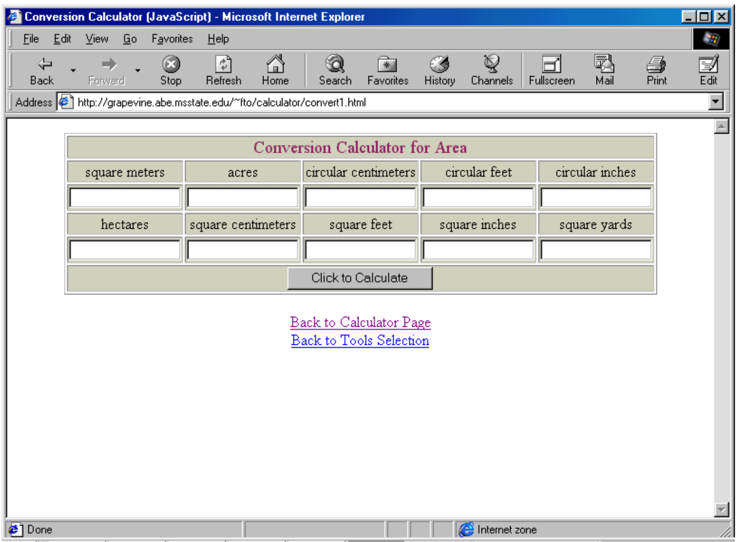
Activities on following page will show you how to use unit conversion calculator.

Activity 3.2:
Using a unit conversion calculator

In this activity we will use an area conversion calculator to convert 50 hectares into square metres. We will need to use our knowledge of scientific notations to interpret the results.

1. Go to Tool Box section of the MCA Online website.

2. Click on Units Conversions link from the contents frame located at the left of open window. A new browser window with links to various conversion calculators will open.



3. Click on Area link to the conversion calculator for area.

4. In the Area Calculator window click once in the hectare box and type 50.

5. Click on click to calculate button to execute your calculation.

6. Note the answer in the square meters box. It shows 0.5e+6. This equals to 0.5×10^6 or 500,000 square metres.

7. Just to check your calculations, click once in the square meters box and type 500000 there.

8. Click on click to calculate button to execute the calculation.

9. Check the hectare box. You should see 50 in this box.

10. Close the window to return to MCA Online Tool box.

This way of working help you backtrack and check the accuracy of your calculation.

Extension Activity:

a. Convert 7 Stones into Kilograms using Mass conversion calculator.

b. Find how long in 5 Miles in Meters.

c. Calculate how many litres would there be in 5 gallons of petrol.

Activity 3.3:
Finding volume of a 3-D shape

In this activity we will use the volume calculator link to calculate the volume of a sphere (ball) with a radius of 12cm.

1. Go to Tool Box section of the MCA Online website.
2. Click on Volume Calculator link from the contents frame located at the left of open window. A new browser window with links to volume calculators will open.
3. Click on the sphere link to open the volume calculator for sphere
4. Scroll down (if necessary) to see fill in fields for angle, height and radius.
5. Fill in the values of angle as 360 (because we want the volume of a fully filled ball) and radius as 12
6. Click on calculate button to see the value of volume in the volume field (7238.229473870883)

Extension Activity:

a. Calculate the volume of 20cm diameter ball when it is only half filled.
b. Calculate the volume of a cylinder 100 cm long and 10cm in diameter.

Online Calculator

The Tool box at MCA Online contains a calculator for your basic calculations. The calculator javascript programming to work on the web. You can use your mouse to enter calculations on four basic operations and special buttons for calculating Pi, square root and trigonometric functions such as sin, cos and tan. It is a base level scientific calculator and does not have many additional features found on hand-held scientific calculators. Though it is handy on the web when you don't have access to a hand-held calculator.

The online calculator keys work as follows:

+ means add

- means subtract

* means multiply

/ means divide

^2 means squared

^3 means cubed

sqrt means square root

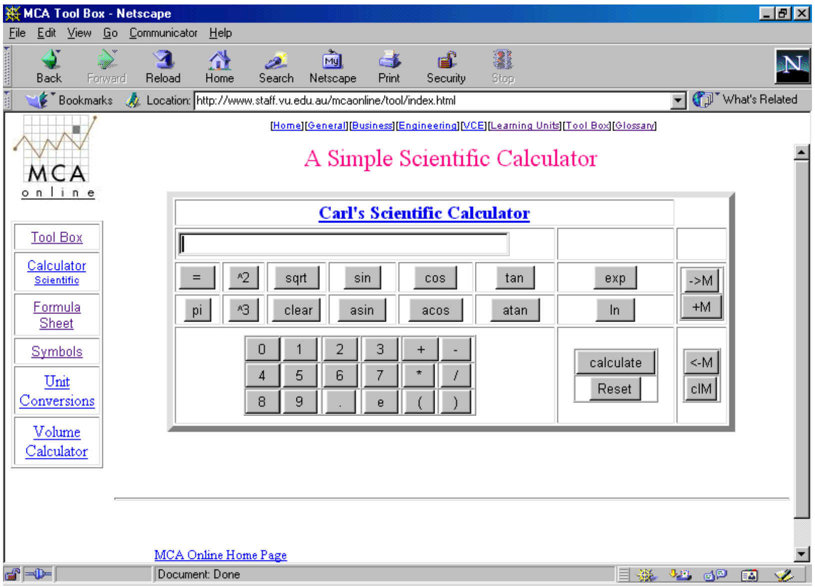
pi means π

Activity 3.4:

Calculate volume of a cylinder using online calculator

In this activity we will calculate volume of a cylinder using the formula V = π r^2h, where V is volume, π

Stands for Pi, r stands for the radius of the cylinder's base and h stands for cylinders height. Your task is to calculate the volume of cylinder that has a radius of 9.5cm and a height of 40cm.



1. Go to Tool Box section of the MCA Online website.
2. Click on Calculator link from the contents frame located at the left of open window. A calculator window will open in the right frame.
3. Using keypad on the screen press Pi * 4.9 * 4.9 * 40 , the calculator automatically uses correct value of Pi on the sreen.
4. Press calculate button to execute your calculation.
5. The answer is shown as 3017.185584507638 on the computer display.
6. Click on Reset button to erase current calculations.

Assessment Task 3

This assessment task is based on your understanding and knowledge from Section 3 of this module. Your tutor will provide you the actual date and time for completing this assessment task.

In this task you will use maths tools and resources available via the Tool Box section of MCA Online to answer questions given to you by your tutor. The Questions Sheet contains 10 problems. Find answers to these problems using MCA online pages where appropriate and submit your answers on an answer sheet to your tutor.

SECTION 4: Using Online Symbols

When you have completed this section, you should be able to perform and demonstrate the following learning outcome in accordance with the assessment criteria and conditions listed below.

Learning Outcome:

Understand symbols and expressions used in online maths

Assessment Criteria:

6. Locate and use maths symbols and formulae to solve problems
7. Solve simple algebraic equations using online interactive links
8. Solve factorising problems using online interactive links
9. Solve interactive Tanagram puzzles

Conditions:

Access to an environment conducive to computer assisted learning.

During learning and assessme0nt activities students will have access to MCA Online Websit0e.

.SECTION 4: Using Online Symbols

Writing maths on a computer is a challenging task specially when using maths symbols and notations. However with the increase in popularity of computer based maths programs and Internet based interactive maths new standards of writing maths on computer are emerging. This unit focuses on introducing online maths symbols and expressions and using this knowledge in participating in online maths activities.

Use of symbols and expressions is unique to mathematics as a subject. At MCA online website you can find conventional maths symbols and forumla lists under Tool box section. The symbols and formula listing contains common mathematical terms and symbols as found in most maths textbooks. If you are looking to find the meaning of a maths notation or symbols, check at Maths Symbols page on MCA online.

Using computer keyboard to write mathematical expressions has resulted in new ways of writing maths. Though unfamiliar to most of us these expressions have been around in computer field for some time and global online communities are adopting these expressions in web based maths writing. MCA online has used following online maths expressions:

Conventional Expression	Online Expression
$3.0 \text{ X } 10^5$	3.0 X 10^5
2^3	2^3
$\sqrt{36}$	sqrt36
$\frac{\sqrt{3}}{2}$	Sqrt(3)/2
$1.07 \text{ x } 10^3$	1.07e+3

Activity 4.1:
Locate and use maths symbols and formulae

In this activity you will practice a task on locating and writing maths expression for interactive online exercises. Your task is to solve a problem based on index laws. The problem is to evaluate:

$$9^{\frac{1}{2}} - 8^{\frac{1}{3}}$$

To solve this problem, first you can look up MCA Tool box for formula sheet on Index Laws.

1. Go to MCA Online Toolbox Page and click on Formula Sheet link to open Maths Formula Sheet 1 in the main frame. Scroll down if necessary to view Index Law-fractional exponents formula. This page will give you some indication of how this problem can be solved.

2. Now go to Learning Units and click on Indices link. This will open Indices learning unit in your browser window.

3. Click on Try More Index Laws Problem from the Links on the Web section of this page. This will open *Webmath* page on *Raising a Polynomial to Some Exponent* page.

4. In Type Your Problem here field carefully type your problem as:

   (9)^1/2 - (8)^1/3

5. Note how this problem is written for online use.

6. Now click on Click here to do the exponent button. In a few moments the page will reload with solution to your problem.

7. Read the solution to your problem. Scroll down the page if necessary. This online calculator solves problems showing every single step involved. You may find that some of these steps are repetitive and unnecessary.

Extension Work

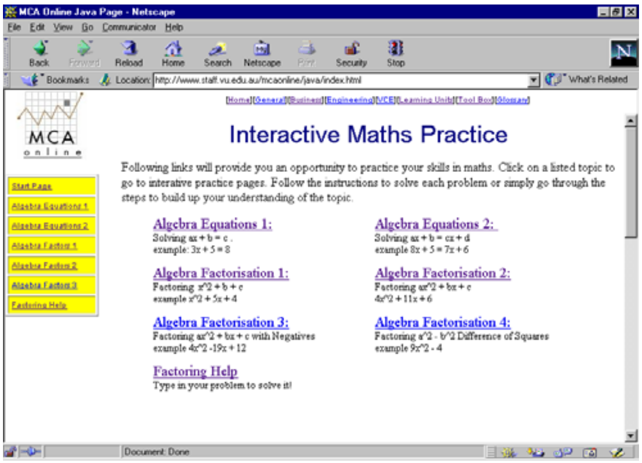
Try following steps shown in this activity to solve following problems:

a. $(x - 3)^2$

b. $(2x + 1)^2 - (x + 1)^2$

Activity 4.2:
Use interactive practice pages on solving simple equations

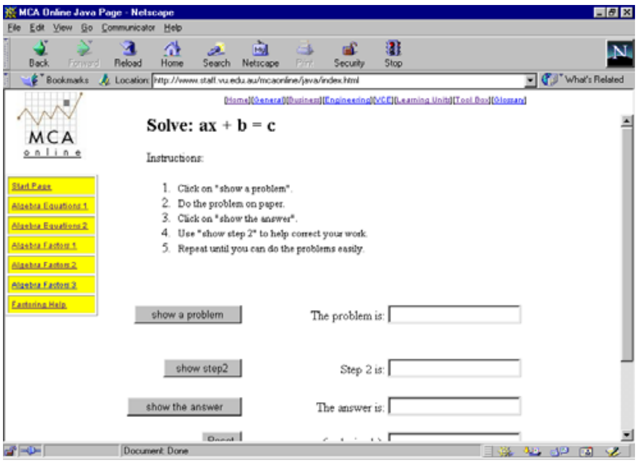
This activity promotes learning in solving algebra equations. MCA online practice pages on algebra allow you to follow step-by-step solution of an infinite number of problems. Your task here is to discover algebra rules for solving these problems by following step-by-step solution done by the program.



1. Go to MCA Online Learning Units Page and click on Practice Online link. This will open up a Maths Interactive Practice page on your screen.

2. Click on Algebra Equations 1 link to open to practice ax +b = c type of equations. Follow on screen instructions on this page to solve the problem.

3. When one problem is solved click on Reset button to erase all entries.



4. Click on Show Problem button to see another problem and follow on screen directions to solve it.

5. Use pen and paper to copy any 5 problems and their step-by-step solution.

Activity 4.3:
Use interactive practice for solving factorising problems

This activity promotes learning in factorising for quadratic expressions. MCA online practice pages on algebra allow you to follow step-by-step solution of an infinite number of problems. Your task here is to discover algebra rules for solving these problems by following step-by-step solution done by the program.

1. Go to MCA Online Learning Units Page and click on Practice Online link. This will open up a Maths Interactive Practice page on your screen.

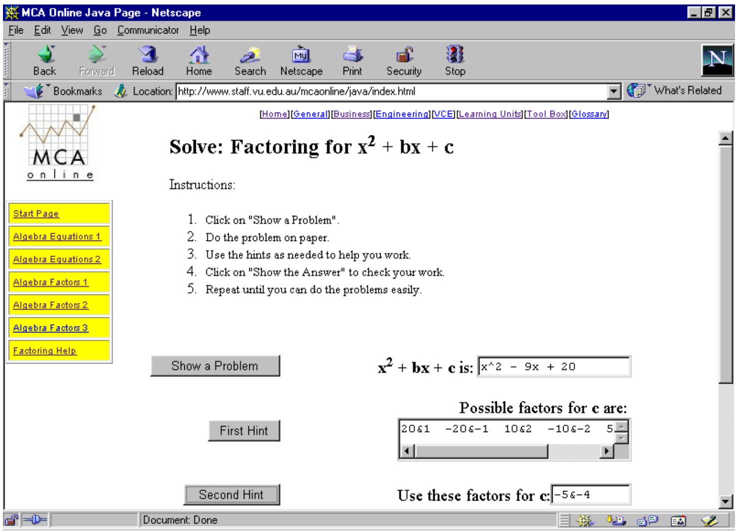
2. Click on Algebra Factors 1 link to open practice exercises on $x^2 + bx + c$ type problems.

3. Follow on screen instructions on this page to solve the problem.

4. When one problem is solved click on Reset button to erase all entries.

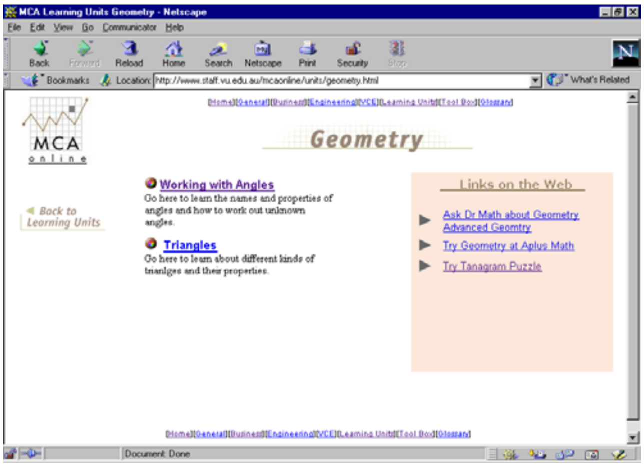
5. Click on Show Problem button to see another problem and follow on screen directions to solve it.

6. Use pen and paper to copy any 5 problems and their step-by-step solution.



Activity 4.4:
Practice design skills with Tanagram puzzles

In this activity you will use 7 pieces of a square to draw various interesting shapes. This is a design manipulation puzzle based on visual perceptions skills. Instead of moving these pieces on a table surface you will use your mouse to drag and rotate these pieces. Here are the steps:



1. Go to the Learning Units section of MCA Online and click on Geometry link. This will open Geometry unit.

2. Click on Try Tangram Puzzle link under the Links on the Web section. This will open a new browser window with Enchanced Mind Tangram Page.

3. Scroll down Tangram Page and click on Tangram Button in a blue square. This will start a new window with Tangram puzzle pieces.

4. Click on Begin button in the Tangram window to start your puzzle.

5. Drag puzzle pieces using your mouse to draw the shape shown on Tangram screen. Use right mouse click to rotate piece. Use double-click to flip parallelogram piece.

6. Draw the puzzle and make sure that pieces do not overlap.

7. Click on >> button to go to next shape.

8. Draw at least two shapes from the collection.

Assessment Task 4

This assessment task is based on your understanding and knowledge from Section 4 of this module. Your tutor will provide you the actual date and time for completing this assessment task.

In this task you will use your maths knowledge and resources available at MCA Online to answer questions given to you by your tutor. Collect Assessment Task 4 Question Sheet from your tutor and answer all questions using MCA online pages where appropriate. Submit your answers on an answer sheet to your tutor.

RESPONSE FORM

In order to update and maintain this module your comments would be most valuable to us.

Please make note of any inconsistencies or errors found in the module on this page and send a copy of your findings to us. We appreciate your help in improving this module.

Section 1

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Section 2

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Section 3

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Section 4

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Return this Form to:

Project Officer
MCA Online Project
Adult Basic Education
Footscray (Nicholson Campus)
Victoria University of Technology
Phone: 03-9284 8873
Fax: 03-9284 8584

Appendix 9

Students’ Questionnaire on MCA Online Module

Your Name:___________________

Course:______________________

Date:______________________

Questionnaire

MCA Online Module

This questionnaire is to be completed by students using MCA Online Module.
Place a tick [✔] next to the correct response.

1. Do you access to the Internet from your home?

   [ ] Yes
   [ ] No

2. Do you have a personal email address?

   [ ] Yes
   [ ] No

3. How often do you access and read your email?

   [ ] Everyday
   [ ] Once or twice a week
   [ ] Less than once a week
   [ ] Never

4. How often do you access Internet from a University computer?

   [ ] Everyday
   [ ] Once or twice a week
   [ ] Less than once a week
   [ ] Never

5. How often do you access Internet from home or a friend's place?

   [ ] Everyday
   [ ] Once or twice a week
   [ ] Less than once a week
   [ ] Never

6. When did you first access MCA Online website?

   Date: ___________________________

7. How relevant did you find the content available from MCA Online website for your maths needs?

    [ ] Very useful for my learning need
    [ ] Sometimes useful for my learning needs
    [ ] Useful just for fun with maths
    [ ] Not sure yet

8. How easy was it for you to use different sections of MCA Online website?

    [ ] Generally easy to use
    [ ] Had problems with some sections
    [ ] Had problems with most sections

9. What sections of MCA Online website were most difficult and confusing to use?

    ____

    ____

10. How easy was it for you to use MCA Online Module?

    [ ] Generally easy to use
    [ ] Had problems with some sections
    [ ] Had problems with most sections

11. What sections of MCA Online Module were most difficult and confusing to use?

    ____

    ____

12. What section(s) of MCA Online website you are likely to use in future?

    [ ] Message Board
    [ ] Learning Units
    [ ] Tool Box
    [ ] Links on the Web
    [ ] Other ____(Please write)____

Appendix 10

Teacher Feedback Questionnaire for MCA Online

MCA Online
Teachers' Workshop
Evaluation Form

Interface

1. How did you like the look and feel of the MCA Online website interface?

2. How easy was it for you to move between different sections of MCA online website?

3. What specific difficulties did you encounter in navigating the website.

4. What suggestions will be give to improve the design?

Content

5. How relevant did you find the content available from this website for your students' needs?

6. If MCA Online website is used as a resource for your department, what changes in the design and content would you suggest?

7. What was the most appealing part of the MCA online in your experience?

8. What section of MCA Online is least likely to be useful for students in your opinion?

Learning

9. How useful did you find the content and links in the Learning Units section?

10. What problems do you anticipate in using MCA Online with your students?

Appendix 11

Research Information Sheet

Victoria University of Technology

INFORMATION TO PARTICIPANTS

We would like to invite you to participate in *a comparative study of online facilitated instruction in business mathematics at the Victoria University TAFE*. Please read this information sheet to learn more about participating in this research study.

Aims of the Study

This is a postgraduate (doctoral) level study being conducted by the School of Education, Victoria University. The study aims to find out how TAFE students use Internet based learning materials to learn mathematics. The study will compare the performance of students who use Internet materials in class with those who use traditional methods of learning. The study would give us a better understanding of how Internet can be used by teachers and students to support face-to-face teaching of mathematics.

Nature of the Study and Procedures

The study is seeking the Diploma in Business and Marketing students enrolled for *the Introduction to Business Mathematics* module to volunteer for participation in this study. As a student you will either be a member of the *traditional class* or the *experimental Internet class* or a non-participating class. Your participation in the study is not a requirement of the subject or course therefore your participation is totally voluntary.

If you are a member of the *traditional class*, you will receive all teaching in the traditional face-to-face manner with the routine testing and assessment as part of the module. As a participant in the study you will be asked to complete a mathematics achievement and a mathematics attitude test at the beginning of the course. These tests will take no longer than 30 minutes in total. Your participation is voluntary and completing these tests will not affect your module assessment in any way.

If you are a member of the *experimental Internet class*, you will receive teaching in the face to face manner in the classroom but this will be supported by course materials on the Internet. You will attend all classes but can access course materials on the Internet from anywhere. The learning activities in the class will use both printed books and Internet activities. As a participant in the study you will be asked to complete a mathematics achievement and a mathematics attitude test at the beginning of the course. These tests will take no longer than 30 minutes in total. You are requested to maintain a journal of your Internet activities during the course. Your participation is voluntary and you can withdraw from the study at any stage without affecting your module assessment in any way.

If you are a member of the non-participating class, you will receive teaching in the traditional face to face manner with the routine testing and assessment procedures as part of the module.

Concerns and Risks

You may be unduly concerned about the affect of this study on your module assessment. Please note that the participation in the study is not compulsory and you can withdraw at any stage. If you are not happy with the experimental Internet class you can request to be moved to the traditional class or the non-participating class. At no stage you will be unduly disadvantaged by not participating in this study. It is proposed that if the success of online facilitated procedures in the experimental group disadvantages you as a member of the either of the other two groups your grades will be adjusted to compensate for any disadvantage. The same compensation in grades will apply to the members of the experimental group if they are found to be disadvantaged by the techniques used.

The data colleted, including your final assessment for the module will remain confidential and will not be disclosed to anyone other than the research team at the School of Education. You will not be identified by name at any stage during the research or in the publications resulting from this research.

Contacts
Any queries about your participation in this project may be directed to the researcher (Syed Javed: ph.9284 8873). If you have any queries or complaints about the way you have been treated, you may contact the Secretary, University Human Research Ethics Committee, Victoria University of Technology, PO Box 14428 MC, Melbourne, 8001 (telephone no: 03-9688 4710).

Appendix 12

Consent Form

ATTACHMENT B

Victoria University of Technology
Consent Form for Subjects Involved in Research
Online Facilitated Class (Treatment Group)

CERTIFICATION BY SUBJECT

I, ____

of ____

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study entitled: ***A comparative study of online facilitated instruction in business mathematics at the Victoria University TAFE***
being conducted at Victoria University of Technology by:

I certify that the objectives of the researcher, together with any risks to me associated with the procedures listed hereunder to be carried out in the experiment, have been fully explained to me by Mr Syed Javed, and that I freely consent to participation involving the use on me of these procedures.

Procedures:

1. Completion of Mathematics Attitude Test
2. Completion of Mathematics General Ability Test
3. Journal Entries for Internet Use
4. Classroom observation of learning with Internet
5. Disclosure of final assessment for the module

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed: **.. }**

Witness other than the researcher: **Date: ....**

..}

Any queries about your participation in this project may be directed to the researcher (Syed Javed: ph. 9284 8873). If you have any queries or complaints about the way you have been treated, you may contact the Secretary, University Human Research Ethics Committee, Victoria University of Technology, PO Box 14428 MC, Melbourne, 8001 (telephone no: 03-9688 4710).

Victoria University of Technology
Participating Teacher's Consent

To Whom It May Concern:

This is to inform you that the researcher Mr Syed Javed has explained to me the details of his research titled *A comparative study of online facilitated instruction in business mathematics at Victoria University TAFE*. He has also explained to me the objectives of the research and any potential risks associated with it.

I freely consent to participate in this study as a teacher in-charge and agree to the conduct of the research involving following procedures:

1. Completion of Mathematics Attitude Test by Students
2. Completion of Mathematics General Ability Test by Students
3. Classroom observation by the researcher
4. Interview with the students and myself
5. Journal entries by students

I Certify that I have had the opportunity to have any questions answered and that the information I provide will be kept confidential.

Signed:

Name:

Address:

Date:

Witness:

Date:

Appendix 13

Percentages Exercise Sheet

<u>EXERCISE 3 (*Percentages*)</u>

LEARNING OUTCOME 2

1. A salesperson works for a straight commission of 3.5% of all sales. Calculate the commission he will receive if his sales were:
   (a) \$35,000 (b) \$125,000 (c) \$385,000 (d) \$53,250

2. Jan works for a fixed amount of \$250 per week plus 1.75% of the sales price of all items sold. Find the total income for the week if the total sales price of all items sold was:
   (a) \$35,000 (b) \$125,000 (c) \$385,000 (d) \$53,250

3. You are an estate agent who has agreed to work for a commission of
   4% on the first \$25,000
   3% on the next \$45,000
   2.5% on the next \$50,000
   2% on the next \$80,000
   1.5% on the amount exceeding \$200,000
   Calculate your commission if you sell properties for:
   (a) \$100,000 (b) \$150,000 (c) \$175,000
   (d) \$210,000 (e) \$355,000

4. You work for a retainer (fixed wage) plus a commission of 4% on all sales. Last week you earned \$409 and your sales were \$3,600. What is your retainer? (i.e. find your weekly fixed wage)?

5. Find the rate of commission if the sales were \$300,000 and the commission amount received is \$750.

6. A discount of 5% is given on an item listed at \$65.99. Find the amount of discount given paid by a customer who receives the discount

7. A product that is listed for \$59.98 is discounted down to \$56. What is the rate of discount given?

8. You bought 300 meters of fabric that has a list price of \$10.99 per meter. You are entitled to a trade discount of 12.5% off the list price. What is the total amount you have to pay for the fabric?

9. Your supplier is offering you the following discounts as an incentive for early payment.

5%	if paid within 10 days
2.5%	if paid within 20 days
1.5%	if paid within 30 days

You have bought $55,000 worth of goods from this supplier. How much should you pay if your bill is paid on the:

(a) 7th day (b) 15th day (c) 25th day (d) 40th day

10. A painter was sent a bill of $350 for materials that he bought which were subject to a trade discount of 20%. What was the list price of the materials the painter bought?

11. A store wishes to get rid of its old stock of fridges that retail for $1200, so it marks them down by 28%. You go to that store and you tell the salesman that you are prepared to buy a fridge provided you receive a further 10% discount if you pay cash. How much should you pay if the salesman agrees to the 10% cash discount?

12. If the salesman in question 12 decides not to give you the 10% cash discount but he offers you a total discount of 38% off the original price, would you be better off under the 38% discount or not? Explain your answer.

13. A store marks up its video cameras by 40% over the cost price from the supplier.
    a. If the store pays the supplier $750 for the video camera, how much will it retail for?
    b. If the store sells a different video camera for $960 what was its cost price?

14. You own a store which sells washing machines. You decided to mark-up the washing machines by 40% on the cost price. Two months went by and nobody showed any interest in the washing machines therefore you decided to sell them for a 10% discount off the marked price. If you sold a washing machine for $504 find the:
    a. original cost price
    b. marked price (list price)

Appendix 14

Interest Exercise Sheet

EXERCISE 4: INTEREST (LEARNING OUTCOME 3)

1. Find the amount of interest earned on a principal of:
   (a) \$5000 at 3.5% per annum over 3 years
   (b) \$8,600 at 5%p.a. over 4 years and 3 months
   (c) \$15,000 at 6%p.a. over 2 years and 6 months
   (d) \$6,700 at 2.5%p.a. over 3 years and 9 months

2. Find the rate of interest (per annum) that will result in a principal of
   (a) \$500 amounting to \$550 when invested for 5 years
   (b) \$2,500 amounting to \$3,300 after 3 years
   (c) \$5,000 amounting t5o \$5625 when invested for 5 years

3. How long would it take a principal of:
   (a) \$18,000 to amount to \$30,397.50 when invested at 9.5%p.a simple interest?
   (b) \$5,000 to double itself when invested at 6%p.a. simple interest?
   (c) \$6,000 to amount to \$6,600 when invested at 5%p.a. simple interest
   (d) \$4,000 to earn interest of \$800 when invested at 4%p.a. simple interest?

4. How long would it take an investment of \$12,500 to amount to \$20,000 when it is invested at 4.75%p.a. simple interest?

5. I have agreed to borrow \$1,500 and repay it over a period of 3 years by making monthly repayments. The interest charged was a flat rate of interest of 6.5%p.a.
   (a) find the amount of interest I have paid
   (b) what is the effective rate of interest charged?

6. A washing machine is advertised for \$1,000. If it is bought on terms, you have to pay a 16% deposit and agree to pay it off in 2 years by repaying \$38.50 per month.
   (a) what is the total interest paid?
   (b) What is the flat rate of interest charged?
   (c) What is the effective rate of interest charged?
   (d) What is the total cost of the washing machine to the customer who bought it on terms?

Appendix 15

Depreciation Exercise Sheet

EXERCISE 6: DEPRECIATION

(LEARNING OUTCOME 4)

1. Using the straight line method of depreciation, for an asset with an original cost of \$12,000 and an estimated life of 10 years
   (a) Find the annual amount of depreciation
   (b) Find the annual rate of depreciation
   (c) Prepare a depreciation schedule for the first 4 years

2. An asset costs \$18,000 and has an expected life of 5 years with a salvage value of \$3,000.
   (a) What is the annual depreciation
   (b) What is the annual rate of depreciation
   (c) Prepare a depreciation schedule

3. A car which costs \$30,000 is to be depreciated on a straight line over a 6-year period. What would the book-value of the car be in 3 years if the salvage value of the car is:
   (a) \$6,000
   (b) \$5,000
   (c) \$0

4. An asset costing \$10,000 has an estimated life of 7 years and is depreciated on a reducing balance method at 13%pa.
   (a) What is the asset's book value at the end of the fifth year?
   (b) Prepare a depreciation schedule

5. A personal computer with an original cost of \$5,000 is depreciated on the reducing balance method at the rate of 35%pa.
   (a) Prepare a depreciation schedule for the first 4 years
   (b) What is the book value of the computer at the end of the 8^{th} year?

6. A printer costing \$800 is depreciated on the units of use method. It is expected to have a life of 80,000 copies. (No scrap value).
   (a) What is the depreciation rate per copy?
   (b) How much depreciation will be charged in a year that produces 30,000 copies?
   (c) What is the book value of the printer after the production of 30,000 copies?

Appendix 16

Linear Equation Exercise Sheet

<u>EXERCISE 7:</u> *Graphing and Break-Even Analysis*

1.Plot the following points:

(a) A(3, 4) (b) B(2, -3)

(c C(-4, -3) (d) D(-5, 2)

(e) E(1.5, 2) (f) F(-3.2, 5)

(g) G(-6.1, 5.2) (h) H(1/4, -1/3)

2. Find the gradient of the lines joining points A and B below:

(a) A(3, 8) B(4, 10)

(b) A(-2, 9) B(3, 14)

(c A(-6, 4) B(1, -10)

(d) A(-8, -2) B(-1, 12)

(e) A(-3, -8) B(-7, -4)

3 (a) find the gradient of the line joining the point A(3, 4) and the point B(2, 6).

(b) Sketch the graph of the line joining points A and B above.

(c Where does your graph cut the Y-axis? (what is the y-intercept)?

(d) State the equation of the line joining the points A and B .

4. State which of the functions below are linear and sketch them

(a) $Y = 2X + 5$

(b) $Y = 6 – 3X$

(c) $Y = X^2 + 3$

(d) $Y = X^2 + 5X +6$

(e) $Y = 4X – 10$

(f) $Y = -5X –2$

5.Solve the following pairs of simultaneous equations graphically

(a) $4X + 2Y =10$ (b) $2X + 3Y = 9$

$X + Y = 4$ $X – 2Y = 1$

Check your answers algebraically

6. The total cost of producing cards is linear.

(Fixed costs being $60 and the variable cost 80 cents per card). Each card sells for $2.00.

(a) state the income equation

(b) state the total cost equation

(c) on the same set of axes sketch the Income and Cost graphs and use it to find the break-even point.

(d) Check your answer to the break-even point using the formula.

7. The total cost of producing calculators is linear.

When 10 calculators were produced the total cost was $1100.

When 50 calculators were produced the total cost was $1900.

Each calculator is sold for $50.

(a) sketch the cost graph

(b) sketch the income graph

(c) how many calculators should be produced and sold to break even? (Solve graphically)

(d) what is the fixed cost?

(e) What is the variable cost per calculator?

(f) State the cost equation

(g) Check the break even point using the formula

8. The total cost of producing handbags is linear.

When 10 handbags were produced the total cost was $1400.

When 100 handbags were produced the total cost was $5000.

The handbags are sold $60 each.

(a) graphically determine the break-even point (sketch the income and cost graphs and find where they intersect)

(b) state the fixed cost

(c) find the variable cost per handbag

(d) state the cost equation

(e) state the income equation

(f) if 70 bags were sold would a profit be made?

How much profit (or loss) would be made?

Appendix 17

Student Questionnaire- Treatment Group

Introduction to Business Mathematics

Sunshine Campus
Victoria University

Student Questionnaire

Name:	
Date:	
Previous Qualifications :	[for example: VCE]
Year qualification achieved:	
Subjects studied at VCE:	
Place and country of birth:	
Languages spoken:	
Access to Internet from Home:	☐ Yes ☐ No
Work Status during this semester:	☐casual work ☐ regular part time work ☐ No work
Your email address:	[If using email regularly]

Appendix 18

Final Test: Mathematics Achievement Post-test

STUDENT ID NO.:………………………..

STUDENT NAME:………………………...

GROUP:…………………………

INTRODUCTION TO BUSINESS MATHEMATICS
VBF 302

FINAL TEST

(1 hour)

1. Solve for X:
   $4X + 26 = 47 - 3X$

2. Apples are \$0.50 per kg. more expensive than pears.
   Six kilograms of apples and four kilograms of pears cost a total of \$39.50.
   Find the price (per kg.) of apples and pears.

3. A computer has a list price of \$2880, but it is sold for \$2448. What is the discount rate offered?

4. An item is sold for \$94. (this price includes G.S.T.). How much is the G.S.T. paid on this item?

5. Last year Paul received an income of $41,600, which was based on a retainer plus a commission of 5.5% on all sales. If his sales were $360,500 what was his weekly retainer?

6. How long would it take a principal of $5,000 to double itself if it is invested at 5%p.a. simple interest?

7. $18,570 is invested at 8%p.a. compounded quarterly over five years.
Determine the:
(a) future value of the investment

(b) interest earned on the investment

8. How long would it take $2,500 to triple itself if it is invested at 12%p.a. compounded monthly?

9. At what rate of interest would a principal of $17,500 accumulate to $20,000 in 2 years if the interest is compounded quarterly?

10. Using the reducing balance method of depreciation, find the book value of a car at the end of the fifth year if it originally cost $39,850 and is depreciated at 12%p.a.

11. Mrs. Jones bought a vehicle for her business for $25,000. The expected life of the vehicle is 5 years with a salvage value of $5,000. Using the straight line method of depreciation

    (a) find the annual depreciation

    (b) prepare a depreciation schedule

12. The total cost of manufacturing radios is linear.

The radios are sold at $150 each.

When 10 radios are produced the total cost is $2,500 and when 50 radios are produced the total cost is $4,500.

(a) sketch the cost graph
(b) find the fixed cost
(c) find the variable cost per radio
(d) state the cost equation
(e) state the income equation
(f) sketch the income graph (on the same set of axes as the cost graph)
(g) use your graph to determine the number of radios that should be produced and sold to break even.

13. The table below shows the prices of a *"1986 bottle of Henschke Mount Edelstone"* wine. for each of the years from 1990 to 1996

YEAR	1990	1991	1992	1993	1994	1995	1996
PRICE ($)	16	20	24	30	41	49	57

Source: *Sun-Herald, 13 October 1996, p.39*

(a) Draw a line graph of the data above
(b) Comment on the trend of the graph

Appendix 19

List of Sample International Websites that link to MCA Online Learning Units

A Sample of International Websites that link to MCA Online Learning Units [Source: www.google.com]

Google Directory - Science > Math > Education

... Online Math Lessons - *http://www.staff.vu.edu.au/mcaonline*/units/index.html **...** *Links* to math terms, mathematicians, math games, and help in algebra and **...**
www.google.com/Top/Science/Math/Education/ - 74k - Cached - Similar pages

The Mathematical Association - supporting mathematics in education

http://www.staff.vu.edu.au/mcaonline/units/numbers/numdir.html **....** Please email your link with a short description and review to *links*@m-a.org.uk **...**
*www.m-a.org.uk/**links**/resources/* - Similar pages

The Standards Site: Glossary

Accredited Programmes- formal qualifications usually awarded ... Adapted from the following website:- **www.staff.vu.edu.au/mcaonline**/units/numbers/numdir.html ...
www.**standards.dfes.gov.uk**/research/glossary - Cached

Education - Math - Science - Web-Katalog - Excite Deutschland

Includes some resource *links*. *http://www.staff.vu.edu.au/mcaonline*/units/index. html · Math Abundance. Tutorial covers trigonometry, vectors, lines,complex **...**
directory.excite.de/science/math/education - 72k - Cached - Similar pages

I NEED help with FACTORING!? - Yahoo!Xtra Answers

Here's some *links* with algebra help (focusing on factoring): http://math.usask. ca/emr/factor.html · *http://www.staff.vu.edu.au/mcaonline*/jav... Good Luck! **...**
nz.answers.yahoo.com/question/index?qid=20080609190222AA1pSgZ - 32k - Cached - Similar pages

Fizzics » AH Physics

http://www.staff.vu.edu.au/mcaonline/units/numbers/numsig.html **...** Note: these *links* might also be useful for AH pupils analysing their investigation data. **...**
mrmackenzie.co.uk/category/ah-physics/ - 33k - Cached - Similar pages

Mathematics

AOkTeacherstuff Math *Links* - huge list of sites - "Math resources for teachers **.....** Measurement - *http://www.staff.vu.edu.au/mcaonline*/units/measure.html **...**
www1.smsd.org/staffdev/elementary/Mathematics.htm - 242k - Cached - Similar pages

[hi.com.au]

Click here for our disclaimer about *links* to other websites. **....** *http://www. staff.vu.edu.au/mcaonline/*units/measure/meaarea.html **...**
*www.hi.com.au/mathszonevic/hot**links**10.asp - 39k* - [Cached] - [Similar pages]

[Making Math Real]

The Annenberg Foundation and the Corporation for Public Broadcasting explores ...
http://**www.staff.vu.edu.au/mcaonline**/units/measure.html ...
www.**arp.sprnet.org**/curric/Dept_Chairs/making_math_real.htm - [Cached]

[Math : Morton College]

http://**www.staff.vu.edu.au/mcaonline**/units/index.html. Click on the "Math Learning Units" ... http://**www.staff.vu.edu.au/mcaonline**/vce/index.html ...
www.**morton.edu**/success_keys/Math.asp - *130k* - [Cached]

[Math Learn Study Guide]

Home. About us. Bibliography. Contact Us. Sequences and Series. Rational Expressions ...
http://**www.staff.vu.edu.au/mcaonline**/units/trig/ratios.html#Solution%201 ...
www.**mathbestlearn.com**/bib.htm - [Cached]

[borrelli]

Radians http://**www.staff.vu.edu.au/mcaonline**/units/trig/trigraddegrees.html ...
Examples http://**www.staff.vu.edu.au/mcaonline**/units/trig/trigraddegrees.html ...
oben.powertolearn.com/obhs/borrelli.html - *52k* - [Cached]

[MathinSite - Mathematics Learning Resources]

MathinSite Post-Diagnostic Quiz Help. ALTHOUGH THIS PAGE IS SPECIFICALLY DIRECTED ... htm and
http://**www.staff.vu.edu.au/mcaonline**/units/trig/trigraddegrees.html ...
mathinsite.bmth.ac.uk/html/mathinsitediagtesthelp.htm - [Cached]

[AT&T Worldnet Service - Directory]

An online maths club for young mathematicians. ... Free Online Math Lessons -
http://**www.staff.vu.edu.au/mcaonline**/units/index.html ...
worldnet.att.net/cgi-bin/webdrill?catkey=gwd/Top/.../Math/Education - *57k* -

[Science: Math: Education in Open Directory from the Jesus Army]

The "Education" section of the "Math" category in the Open Directory from the ...
MCA's Free Online Math Lessons **www.staff.vu.edu.au/mcaonline**/units/index.html
www.**jesus.org.uk**/pod/Science/Math/Education - *109k* - [Cached]

Appendix 20

Weekly Assessment Tests – Version A and B

[redacted]

5

VBF302 INTRODUCTION TO BUSINESS MATHEMATICS

TEST 3A

1. Find the amount of interest earned if \$6,250 is invested at $4\frac{3}{4}$ %p.a. (simple interest) over 6 years.

?

2. What principal will amount to \$17,250 if it is invested for 2 years and 6 months at 6%p.a.
   (a) simple interest

   ~~P = \$17250.~~
   ~~R = 6%~~

   I = PRT.
   ~~17250 - P = P × 0.06 × 2½~~.
   ~~17250 - P = 0.15 P~~.
   ~~17250 = 0.15 + 1P~~
   ~~17250 = 1.15P~~.
   ~~17250/1.15 = P~~

   \$520. X

   (b) compounded quarterly

   ?

3. How long would it take a principal of \$4,500 to double itself if it is invested at 6%p.a. simple interest?

   ~~15½ yrs~~ 16 yrs. close

   ?

PTO

4. Find the interest earned if a principal of $7,380 is invested at 5%p.a. compounded quarterly for 4 years

$1107.

X

5. How long would it take a principal of $6500 to amount to $9621.60 if it is invested at 8%p.a. compounded semi-annually?

~~3 years.~~ 6500 × 8% = 520

for 6 mths it is = 260.

for the Principal amt to $9621·60

it takes 36 yrs.

X

6. A principal of $6000 amounts to $7622.94 when invested for 4 years with interest compounding monthly. What is the annual rate of interest?

I = PRT.

P = 6000.

T = 4yrs.

I = 7622·94 − 6000 = 1622·94.

1622·94 = 6000 × R × 4.

$\frac{1622 \cdot 94}{6000} = R$.

0·27 = R.

3% = rate of interest.

R = I/~~PT~~.

= ~~1622·94~~ / ~~6000×4~~ = ~~1622·94~~ / ~~24000~~

= ~~0.06~~.

X

[redacted]

VBF302 INTRODUCTION TO BUSINESS MATHEMATICS [redacted]

TEST 3B

1. What principal will amount to $7,680 if it is invested for 3 years and 6 months at 8%p.a.
   (a) simple interest

$T = 3.6$ yr
$R = 8\% = 0.08$
$A = 7{,}680$

$P = \dfrac{7{,}680}{1 + (0.08 \times 3.6)}$ 3.5

$= \dfrac{7{,}680}{1 + 0.288} = \dfrac{7{,}680}{1.288}$

$\boxed{5962.73}$ ✗

1

   (b) compounded semi-annually

$7{,}680 = P(1 + 0.04)^{7.2}$

$7{,}680 = P(1.04)^{7.2}$

$7{,}680 = P \; 1.32629$

$\dfrac{7{,}680}{1.32629} = P$

$\boxed{5790.59} = P$

$i = \dfrac{8}{2} = 4\% \quad 0.04$

$n = 3.6 \times 2 = 7.2$

$3.5 \times 2 = 7$

Correct method

1

2. A principal of $8,340 is invested for 7 years at $5\frac{1}{4}$%p.a. simple interest. How much interest did it earn?

$P = 8{,}340$
$T = 7$ yrs
$R = 5\frac{1}{4}\% \quad 0.0525$

$I = P \times R \times T$

$= 8{,}340 \times 0.0525 \times 7$

$= \boxed{3064.95}$ ✓

2

3. Find the interest earned if a principal of $8,500 is invested at 6%p.a. compounded monthly.

5 yrs

$A = P(1 + i)^n$

$= 8{,}500 \,(1 + 0.06)^{60}$

$= 8{,}500 \,(1.06)^{60}$

$= 8{,}500 \times 32.988$

$= 280.398$

$P = 8{,}500$
$n = 5 \times 12 = 60$
$i = 6\% = 0.06 \div 12 = 0.005$

interest earned $= 8{,}500 - 280398$
$= 271\,898$

1

PTO

4. How long would it take a principal of $3,600 to double itself if it is invested at 5%p.a. simple interest?

$P = 3,600$
$R = 5\% = 0.05$
$I = 3,600$

$T = \frac{I}{P \times R}$

$T = \frac{3,600}{3,600 \times 0.05}$

$T = \frac{3,600}{180}$

$T = 20$ years

2

5. A principal of $8,000 amounts to $11,876 when invested for 4 years with interest compounding quarterly. What is the annual rate of interest?

$P = 8,000$
$A = 11,876$
$N = 4 \times 4 = 16$

$i = \left(\frac{A}{P}\right)^{\left(\frac{1}{n}\right)} - 1$

$i = \left(\frac{11,876}{8,000}\right)^{\left(\frac{1}{16}\right)} - 1$

$i = 1.4845^{\left(\frac{1}{16}\right)} - 1$

$i = 1.025 - 1$

$i = 0.025 \times 100$

$= 2.5 \times 4$ → 10% pa

2

6. How long would it take a principal of $3,800 to amount to $5,118 if it is invested at 6%p.a. compounded quarterly?

$P = 3,800$
$A = 5,118$
$i = \frac{6}{4} = 1.5\%$ 0.015

$n = \frac{\log\left(\frac{A}{P}\right)}{\log(1+i)}$

$n = \frac{\log\left(\frac{5118}{3,800}\right)}{\log(1 + 0.015)}$

$n = \frac{\log 1.35}{\log 1.015}$

$n = \frac{0.130334}{0.006466}$

$n = 20.16 \div 4 = 5$ yrs

2