1 Chapter 1: Context of the Study

1.1 Background to the Study

In the new millennium teaching and learning of mathematics is facing new challenges in the vocational and technical education sector in Australia. Rapid progress and developments in the 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) appear to be amongst the top performing countries of 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, 2006). 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 (A. 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 Vocational Education and Training (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; P. 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 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 to have 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 Gadani, 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 researches 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 (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.

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.

![Paradigm Grid for online learning. Adapted from Coomey and Stephenson (2001).](image)

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 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.

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 on 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 Practice Described – Cycle 1 and Cycle 2. 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 named as Practice Described – Cycle 2. This chapter 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.


Cashion, J., & Palmieri, P. (2002). *The secret is the teacher: the learner's view of online learning*. Adelaide, South Australia: NCVER.


