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 knowledge and become familiar with the application and use of technology in learning mathematics. One of the main purposes of this study was to investigate and understand how an online learning environment in mathematics can be designed and used to support and enhance students’ skills and knowledge in mathematics. The design and development of the web based learning environment was guided by the desire to promote the use of new learning technologies in mathematics teaching and provide opportunities for inclusion of more authentic problem based tasks and collaborative learning. 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 traditional based 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, and use of online learning environment in mathematic activities. The role of teacher in this blended learning environment was examined in the context of her pedagogical, social, managerial and technical responsibilities. In addition, the interaction of technology and the teacher was also analysed using Valsiner’s zone theory as adapted by Goos (2003).

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 mathematics teaching. 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 7.1 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 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 when put 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 on 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 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 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 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 from being distracted to 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, flexible 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 affect 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 of 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 designing of an online learning environment in mathematics teaching in a blended learning format and 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 different design criteria. 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 of supporting and learning of mathematics within a specific mathematics module. 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, i.e. content on the page does not change by actions of the user, and dynamic, i.e. 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 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 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 are valued by students and increase 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 to participate due to problems in typing 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 roles and the extent and nature of learning in this format depends on number of factors including teachers’ instructional beliefs, 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 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.

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 appear to have any effect on their results in the traditional pen and paper tests. 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 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 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 can be explored to extend our understanding in:

a. How new online learning environments can be developed and used for teaching mathematical skills required for emerging technology rich workplaces?

b. How vocational mathematics is 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 can be updated and customised for supporting and enhancing mathematics teaching in other trade and vocational areas. Further research can identify gaps in the learning environment design and implementation process.
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 teacher as co-investigator and the involvement of 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 broadly 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.

When a number of students from both the treatment and control groups dropped out from 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 four and five 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 designer 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 student’s 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 effecting teaching practice with technology compared to
teacher’s 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 vocational education and training 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.


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


