An examination into the effects of incorporating collaborative learning methods in a core first-year mathematics subject

A Thesis Submitted in Fulfilment of the Requirements for the degree of Doctor of Philosophy

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Certificate of authorship

I, Sabita Maria D'Souza, hereby certify that the work presented in this thesis has not been previously submitted for a degree, nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

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I also certify that I have received ethics clearance from all appropriate authorities in accordance with the policies of the University of Technology, Sydney on human and animal research.

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(Sabita D'Souza)                                12/12/2005
Dedication

I dedicate this thesis to my loving family:

To my beloved parents-
Dr. Peter Joseph Francis D'Souza
&
Mrs. Maria dos Anjos D'Souza

and my sister -

Nisha Maria D'Souza

My source of strength, courage and love
Preface

The following are refereed research publications relating to this thesis:


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Abstract

This project aims to examine the effects of incorporating collaborative learning methods extensively in a core first-year mathematics subject and to investigate students' individual learning style preferences, their attitudes towards group-work in mathematics and the objectives for setting group work, their attitudes towards using computers, in particular, Mathematica and their concerns regarding the assessment of group-based work.

Following the rapid increase in the use of technology in education over the last decade, one would perhaps expect to find an overabundance of literature regarding the effects of its use. However, the number of technology related research studies has been surprisingly low, especially those pertaining to the curriculum area of Mathematics at the tertiary level. The availability of quality software, the need for curriculum redesign, and limited research on the effectiveness of computers as a teaching tool, are factors to have hindered the rate of implementation and of subsequent research.

Also, despite the rapid growth in the use of collaborative methods of learning, and widespread belief in the importance of such methods, there have been calls for increased research especially at the tertiary level, and particularly in engineering education – looking at students who have to study mathematics because it is a requirement and not because they are majoring in mathematics, therefore needing to determine how best to make their learning a meaningful and enjoyable experience.

This project aims to investigate the effects of incorporating a rich collaborative learning based curriculum in either face-to-face or computer-supported environments in the subject Mathematical Modelling 1. The carrying out of this project is a response to the lack of research in a curriculum area of tertiary mathematics. Within the context of mathematics, issues of attitude, gender differences, motivation and achievement are considered. The chief purpose of this investigation is to explore the effectiveness of collaborative learning in mathematics at university, and to provide some insight as to what degree, if any, the use of such methods enhance mathematics learning.
The research uses an experimental methodology, an attitudinal questionnaire and in-depth interviews to elicit students' feelings and/or opinions toward the incorporation of collaborative learning. The questionnaire sought demographic information from the students, namely, name, age, gender, length of stay in Australia and language spoken at home, and investigates the role of these factors in the effectiveness of, and interest during the tutorial and laboratory sessions – a time when students were working on collaborative-based activities.

This project maintains interest in the use of collaborative problem solving, and the belief that the findings could be of international significance if the effectiveness of this style of learning can be finnly established. It is also hoped that grounding the collaborative activities in the literature, and providing statistical and theoretical support for their use might promote them more widely in mathematics in particular and more generally, across universities in Australia.

The broad issue of whether the use of collaborative learning enhances mathematics learning can be broken down into a number of specific inquiries. The key research questions may thus be expressed as follows:

1. What are tertiary students' preferred learning styles?
2. What are students' opinions about group work in mathematics?
3. Does collaborative group work foster a deep, meaningful understanding of mathematics?
4. What are students' attitudes about using CAS such as Mathematica?
5. What are students' attitudes about the assessment of group-based work?
6. Are there any differences in students' learning style preferences across the various demographics?
7. Are there any differences in students' attitudes towards collaborative learning methods across the various demographics?
8. Are there any differences in students' attitudes towards the use of Mathematica across the various demographics?
9. Are there any variations in students' attitudes towards the assessment of group work in mathematics across the various demographics?
This study does not claim to fill the void into the effectiveness of computers or collaborative learning methods, but should provide greater insight and support to future research.
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Figure 8.26 Scatter plot of final examination versus tutorial and laboratory marks for the population of students that completed the questionnaire with markers set by sex

Figure 8.27 Scatter plot of final examination versus tutorial and laboratory marks for the population of students that completed the questionnaire with markers set by number of years in Australia

Figure 8.28 Scatter plot of final examination versus tutorial and laboratory marks for the population of students that completed the questionnaire with markers set by language spoken at home

Figure 9.1 Action research cycle
Chapter 1

Background and introduction

1.1 Impetus for the investigation

The impetus for carrying out this research project came out of my five-year involvement in lecturing and tutoring within the Department of Mathematical Science at the University of Technology, Sydney (UTS). I lectured and tutored a number of undergraduate mathematics and statistics subjects, primarily first-year subjects. I was very involved with one subject in particular, namely, Mathematica Modelling 1 (MM1), which is a core first-year mathematics subject that all Engineering students have to take to get credit towards their degree programs. I tutored and lectured this subject on a number of occasions during my employment at UTS.

Computer technology was emphasised with the use of the computer algebra system, Mathematica being used in the delivery of lectures and it was promoted for student use. An area that was not highly emphasised was students' individual learning style preferences, that is, do they have a preference to learn by themselves or collaboratively in groups, or a combination of both styles. My observations, personal experience, discussions and readings led me to consider the importance of offering students a variety of learning styles in different environments. The introduction of collaborative learning methods in either face-to-face or computer-supported environments by me was an exciting and innovative example of these beliefs.
This research investigation was designed to study the effectiveness of collaborative learning as it relates to learning outcomes at the tertiary level, for engineering students studying mathematics. The aims of this thesis were to examine the effects of incorporating collaborative learning methods extensively in the MMI subject for the first time since the subject had been on offer by investigating:

- students' individual learning style preferences,
- their attitudes towards group-work in mathematics and the objectives for setting group work,
- their attitudes towards using computers, in particular, Mathematica, and
- their concerns regarding the assessment of group-based work.

The research questions and further objectives will be outlined in later sections of this chapter.

1.1.1 The subject under investigation

The teaching unit of investigation in this project was the core first-year subject, Mathematical Modelling 1 (MMI). It is a six credit-point course whose only prerequisite is an assumed knowledge of 3-Unit mathematics at high school. It is a subject that is offered in both Autumn and Spring semesters at UTS with a major intake in Autumn. The enrolment during the Autumn semester averages around 450 students while the Spring semester intake has an average of approximately 150 students. I decided to use the Autumn intake as my sample mainly because it would give a larger sample.

The objectives of this subject state: on completion of this subject, students are meant to be able to:

a. understand the relevance of mathematics to engineering science and practice;
b. understand the way in which mathematics can supply useful tools and resources to model real world problems;
c. use mathematical terminology and concepts;
d. use formal and informal language to demonstrate understanding of these concepts;
e. demonstrate a high level of skill in the computational techniques of the subject;
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f. demonstrate understanding of the theoretical results which justify the use of these techniques;
g. communicate the above knowledge clearly, logically and critically;
h. use the computer algebra system Mathematica to perform calculations and explore mathematical ideas relevant to the subject content;
i. be able to apply the subject matter covered in lectures, tutorials and assignments to previously unseen problems; and
j. be aware of the historical context of mathematical development.

Topics taught in this subject include:
a. presentation of a collection of physical problems;
b. functions and their relationship to measurement and the interpretation of physical results;
c. differentiability;
d. differential equations arising from physical problems;
e. solution by series;
f. growth and decay problems;
g. oscillatory motion;
h. trigonometric functions and inverse trigonometric functions;
i. integration;
j. the logarithm function;
k. inverse functions;
l. methods of integration; and
m. introduction to nonlinear oscillations.

The computer algebra system Mathematica is used throughout the subject as an aid to computation, graph plotting and visualization.
1.2 A brief look into the current state of research

1.2.1 Computer technology

Following the rapid increase in the use of technology in education over the last decade, one would perhaps expect to find an overabundance of literature regarding the effects of its use (Dix, 1998). However, the number of technology-related research studies is not many, especially those pertaining to the curriculum area of mathematics at the tertiary level. Lack of quality software, the need for curriculum redesign, and limited research on the effectiveness of computers as a teaching tool, are factors which may have retarded the rate of implementation and of subsequent research. Computers have the potential to reshape the way education is conducted (Ward & Lee, 1997). While the use of technology in education is encouraged in the mathematics curriculum, its integration is not widespread in mathematics courses at universities. Every observation made has its own exceptions.

In particular, research conducted by King et al. (2003) and Muller (2003) focused on the various ways in which technology can impact upon the teaching and learning of mathematics at the tertiary level, primarily looking at the present-day role of technology in teaching at the post-secondary level, on the perspectives envisaged for the future and on broader research questions that are affected by the use of technology. It centred mostly on the use of technological tools for supporting students’ learning, particularly via visualisation, computation and programming. However, it also recognised the role of such tools for demonstration by the teacher, presentation of lessons via distance learning, student assessment and student drill.

Much has been written about the need for general computer technology education (Jarvinen, 2001). Consequently, this research study does not aim to authenticate the need for it any more. Rather, the investigation aims to explore students’ working with the computer algebra system, Mathematica, within the context of the subject MM1 so as to get an understanding of their concerns and expectations when using the technology. In terms of speed and functionality, the program Mathematica is quite amazing and powerful. It has become an indispensable tool for research in many areas of the sciences
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and mathematics. From the evaluation of mathematical formulas to the graphing of three-dimensional data over time, it can handle almost anything one needs to process or analyse in mathematics. It is relatively user-friendly and doesn’t require much time to put it to productive use. However, with all that capability, it is still not as frequently used and integrated into mathematics subjects as much as I would like to see.

Concerns about the lack of empirical research in computer technology education are still echoing (de Vries, 1999; Custer, 1999). Moreover, in spite of the increasing impact of technology on society there is not enough evidence about the impact of technology education on students' learning about technology. This situation is described by de Vries (1999, p.149), "Although in several countries by now we have had at least a decade to prove the reality of the impact that we claimed Technology Education would make, we do not (yet) have an empirical basis for that". It has been widely agreed that technology teaching should aim to increase knowledge about the technological world created by us (Jarvinen, 2001). The International Technology Education Association (2000, pA) writes, "Students who study technology learn about the technological world that inventors, engineers and other innovators have created"

It is also important in computer technology education to make students work with technology. The International Technology Education Association (2000, p5) states, "One of the great benefits of learning about technology is also learning to do technology, that is, to carry out in the laboratory-classroom many of the processes that underlie the development of technology in the real world'. Consequently, students should be able to think and use problem-solving techniques as much as possible and they should be driven through the processes characteristic to computer-based technology (Jarvinen, 2001).

However, it has to be emphasised that just using computers and introducing the latest equipment in the classroom does not meet the goal of educating students about, nor through, computer technology. As Harrison (1994) states, students should be given opportunities, regardless of the materials used, to act technologically. They should be supported to use their thinking skills in designing things. They should also be given
opportunities to participate in innovative problem-solving processes in a way that can be considered technological.

1.2.2 Collaborative learning

The concept of collaborative learning - the grouping and pairing of students for the purpose of achieving an academic goal – has been widely researched and advocated by many in the professional literature. The term "collaborative learning" refers to an instruction method in which students at various performance levels work together in small groups toward a common goal. The students are responsible for one another's learning as well as their own. Thus, the success of one student helps other students to be successful.

Despite the rapid growth in the use of collaborative methods of learning, and widespread belief in the importance of such methods, there have been calls for increased research especially at the tertiary level (Oates, 1998), looking at students who have to take mathematics because it is a requirement and not because they are majoring in mathematics. Therefore there is a need to determine how best to make their learning a meaningful and enjoyable experience (Oates, 1998).

Although many of the research studies on collaborative learning have been done at the primary and secondary levels, there is an increasing number of research studies on its effectiveness at the tertiary level, but not as much in the engineering and mathematics domains. Also, the majority of the research in collaborative learning has been done in non-technical disciplines (D'Souza & Wood, 2003d).

Yackel et al. (1991) note that more research needs to be done into the processes involved in collaborative learning. Davidson and Knoll (1991) suggest that further research is necessary to determine the optimal conditions for raising student achievement and individual accountability. Slavin (1990a, p52) notes that although literature reviews have found that collaborative learning methods are beneficial at lower levels of schooling, "more research is needed to gauge cooperative learning's effectiveness at senior high ... and/or instilling higher order concepts".
1.3 Definition of key terms

To clarify the research questions posed below, several terms need to be defined more fully and these are discussed below:

1. **Collaborative learning** refers to learning in an environment where students in small groups share ideas and work together to complete tasks.
2. **Mathematica** is a widely-used computer algebra system originally developed by Stephen Wolfram (see www.wolfram.com for more details).
3. **Motivation** is a general term used to encompass perceptions about task difficulty, task worth, willingness to stay on task and task enjoyment.
4. **Computer-supported environment** uses computers and software such as Mathematica to carry out work. Learning takes place primarily in a computer laboratory, but can also take place in a classroom, or at home.

1.4 Aims and objectives

This research project aims to investigate the effects of incorporating a rich collaborative-learning based curriculum in either face-to-face or computer-supported environments in a core first-year mathematics subject. The carrying out of this project is in response to the lack of research in the area of tertiary mathematics. Within the context of mathematics, issues of attitude, gender differences, motivation and achievement are considered. The chief purpose of this investigation is to explore the effectiveness of collaborative learning in mathematics at university, and to provide some insight as to what degree, if any, the use of such methods enhance mathematics learning.

1.5 Research questions

My research uses an experimental methodology, which included attitudinal questionnaires and in-depth interviews to elicit students’ feelings and/or opinions toward the incorporation of collaborative learning. The questionnaire sought
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demographic information from the students, namely, age, gender, number of years spent in Australia and language spoken at home, and I investigated the role of these factors in the effectiveness of, and interest during, the tutorial and laboratory sessions - a time when students were working on collaborative-based activities.

This investigation maintains interest in the use of collaborative problem solving, and the belief that the findings could be of international significance if the effectiveness of this style of learning can be supported. It is also hoped that grounding the collaborative activities in the literature, and providing statistical and theoretical support for their use, might promote them more widely in mathematics in particular and more generally, across universities in Australia.

In summary, the broad issue of whether the use of collaborative learning enhances mathematics learning can be broken down into a number of specific inquiries. The key research questions may thus be expressed as follows:

1. What are tertiary students' preferred styles?
2. What are students' opinions about group work in mathematics?
3. Does collaborative group work foster a deep, meaningful understanding of mathematics?
4. What are students' attitudes about using CAS such as Mathematica?
5. What are students' attitudes about the assessment of group-based work?
6. Are there any differences in students' learning style preferences across the various demographics?
7. Are there any differences in students' attitudes towards collaborative learning methods across the various demographics?
8. Are there any differences in students' attitudes towards the use of Mathematica across the various demographics?
9. Are there any variations in students' attitudes towards the assessment of group work in mathematics across the various demographics?
1.6 Significance and rationale for this investigation

Considering the strong academic records of most students who choose to do an engineering degree, attrition rates from these courses are dramatic. In a study conducted by Astin (1993), out of nearly 25000 students at over 300 institutions in the USA, only 43% of the first-year engineering students went on to graduate in engineering. A common (but inaccurate) explanation of high student attrition rates from engineering is that most of those who leave lack the academic ability to cope with the rigours of the discipline. In actual fact, studies have shown little difference in academic status between students continuing in engineering and students leaving (Besterfield-Sacre et al., 1997). A more comprehensive explanation appears to involve a complex set of factors that include students' attitudes toward engineering, their self-confidence levels, and the quality of their interactions with instructors and their peers, along with their aptitude for engineering (Astin, 1993; Besterfield-Sacre et al., 1997; Cross, 1993; Felder et al., 2000). Students' attitudes toward engineering and their confidence levels are strongly related to their classroom experiences (Felder et al., 2000).

Astin (1993) showed that compared to majors in other disciplines, engineering majors are more dissatisfied with the quality of instruction they receive at university and with their overall university experience, and offered convincing evidence that the prevalent model of instruction in engineering with its extensive reliance on lecturing and individual work plays a major role in the high dissatisfaction level and therefore in student attrition (Felder et al., 1998).

Active and collaborative learning techniques can result in higher performance and longer information retention compared to traditional methods. Integrating mathematics, science and engineering courses is an effective means of teaching students to deal successfully with cross-disciplinary problems and integrating communication/language study into engineering, science and mathematics courses is an effective way to improve the performance of engineering students in oral and written communication (Dees, 1991; Felder & Brent, 1994; Schwartz, 1996).
Australian studies have demonstrated that the first year at university is a period of adjustment or transition for beginning students, whether they are school leavers, mature age, international students or students with complete or incomplete postsecondary qualifications (McInnis, 1993, 1994; McInnis & James, 1994, 1995; McInnis et al., 2000). Clearly the transition process varies markedly for individual students within these broad groups, and for some the transition process is more difficult than for others. Regardless of background variables such as age or previous educational experiences, research supports the need to pay particular attention to university students' early experiences. Light (2001) refers to the powerful impact of "critical moments and events" (p205) which students often recall as being clustered in the first few weeks of the academic year, and which set the tone for the quality of subsequent experiences.

University orientation programs in various forms play an important role in the early experiences of many students. These orientation programs traditionally devote most attention to integrating new students at a social level, yet research suggests that academic orientation and integration is equally, if not more important (Tinto, 1997) and requires careful planning and organisation. In particular, students benefit from being able to interact with fellow students and academics in connection with their studies (Pascarella & Terenzini, 1998). These shared connections need to be made early in students' experiences to instil a shared sense of belonging to a learning community.

1.6.1 Transition from school to university

Tertiary students' first-year experiences appear to be crucial to their personal adjustment and academic performance (Pargetter et al., 1998). First-year at university for many students entails a considerable time of transition and change, particularly for those entering tertiary education directly after the end of their high school education. The transition from school to university involves adjusting to different learning environments and assessment systems, different perspectives on discipline-based knowledge and different teaching practices (Pargetter et al., 1998).

Collaborative learning, where implemented, has been recognised as an effective transition factor in supporting the development of a learning community and by enhancing higher order cognitive abilities (Johnson & Johnson, 1992). Collaborative
learning is generally understood to be "learning that takes place in an environment where students in small groups share ideas and work collaboratively to complete academic tasks" (Davidson, 1990a, p362). To collaborate means to share work. This means that whenever possible, learning tasks are divided up amongst group members so that they share the work equally and thus help make the project successful.

At the other end of a degree program, when students are moving to the workforce, there is recognition that traditional fokus of university course delivery are often inappropriate in preparing students for the changing workforce (Drucker, 1995). Generic skills are becoming increasingly valuable to university graduates and due to the flexibility of careers and the workplace, collaborative learning is a tool that has much to offer both students and educators.

The traditional concept of collaborative learning as a group meeting regularly to work together highlights only one type of collaboration between students regarding their learning. Other less intensive activities that can be considered under a broader definition of collaborative learning include seeking assistance from a more senior student, swapping lecture notes, using classroom free time to work on subject-related matters rather than social discussions, and spontaneous discussion of academic work in social settings (Dalziel & Peat, 1998).

Thus, viewed in this more general sense, collaborative learning is probably a common experience of many students regardless of any attempts by universities to foster such techniques. Nevertheless, there are ways in which university programs can increase the likelihood of collaboration and support this type of learning (Dalziel & Peat, 1998).

At university, most engineering mathematics classes still consist of instructors talking and writing on the board and students sitting and listening (or not listening) (Felder et al., 2000). Many instructors are reluctant to move away from the familiar and comfortable teaching methods with which they were taught, especially if they believe that changing their methods would require substantial expenditures of time and could hinder their chances for promotion. They will only consider doing so if they are first made aware of the need for change, presented with alternative methods, given
convincing evidence of the effectiveness of such alternatives, and assured that adopting such methods does not necessarily require sacrificing syllabus coverage or spending less time on research (Felder et al., 2000).

A requirement for significant educational reform is therefore the establishment of instructional development for programs that provide this information and these assurances (Dalziel & Peat, 1998). An additional necessary condition for reform is for instructors to be convinced that their efforts to improve teaching and learning will not work against their career advancement, and that, if successful, the efforts can in fact work in their favour (Dalziel & Peat, 1998).

Small-group collaborative learning provides an alternative to both traditional whole-class expository instruction and individual instruction systems. This method of learning can be applied with all major topic areas in tertiary mathematics. According to Neyland (1994, p35), collaborative learning is one of a range of valuable approaches, based on the premises that:

*each student has an individual thinking style that needs to be identified and used;*
*individual thoughtful concentration and knowledge construction are important components of the and problem-solving process; the and problem-solving process is enhanced when individuals pool in their ideas, challenge & elaborate on each other's thinking.*

If engineering mathematics instruction is to help students think mathematically, understand the connections among various mathematical facts and procedures, and be able to apply formal mathematical knowledge flexibly and meaningfully, then Davidson (1990b, p53) offers the following motivation for employing collaborative learning methods in mathematics classes:
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- Small groups provide a social support mechanism for the learning of mathematics:
- Small group learning offers opportunities for success for all students:
- Mathematics problems are ideally suited for group discussion in that they (usually) have solutions that can be objectively demonstrated;
- Mathematics problems can often be solved by several different approaches. Students in groups can discuss the merits of different proposed solutions and perhaps learn different strategies.
- The field of mathematics is filled with exciting and challenging ideas that merit discussion. One learns by talking, listening, explaining, and thinking with others...
- Mathematics offers many opportunities for creative thinking. Students in groups can often handle challenging situations...

1.7 Confines of the investigation

Research into the effectiveness of collaborative learning methods in face-to-face and computer-supported environments may well be an ambitious study. For the purposes of this investigation, a number of modifications are needed to make the study manageable. This study was limited to one subject – Mathematical Modelling 1 and one cohort of students - Engineers. This was done for the following reasons:

1. the lack of research investigating the needs, concerns and experiences of engineering students who do not major in mathematics but who have to study it as part of the requirements of their professional degree programs;
2. the large class size - on average of over 400 students enroll in this subject during the Autumn intake, providing a good sample size to carry out the investigation; and
3. the opportunity to introduce new learning methodologies, in this instance, group-based work during the tutorial and laboratory sessions;

Research into the use of collaborative learning and computer technology in mathematics at the undergraduate level is important and necessary. Clearly, study findings pertaining to one curriculum area will not be directly translatable into another area – each has its own peculiarities. Also, the use of computer technology has traditionally been associated with mathematics, and changes in technology have had direct repercussions on the mathematics curriculum (Dix, 1998). Amongst all core-learning areas,
mathematics has generally proven to be the most responsive to these changes and, for the purposes of this project, was considered to be highly appropriate.

### 1.8 Ethics approval and consent

Prior to commencement of this project, a number of ethical requirements had to be considered. Consent from the Human Research Ethics Committee (HREC) at the University of Technology, Sydney (UTS) involved the submission of a research proposal outlining the aims and objectives, details of subjects participating in the study, methodology and test measures to be used in the study (see Appendix A1). In accordance with ethics requirements, an information letter and consent form was provided to each student and only those that consented were used in the investigation. A copy of the information letter and consent form is included in Appendix A2. A final ethical proviso stipulated confidentiality, whereby no student was identifiable by name and all data be coded during the data analysis stage.

### 1.9 Thesis precis

Discussion in this chapter included the research questions addressed, the significance of the study, limitations, information about the setting of the study, and ethical considerations. As an introduction, this chapter has provided the foundation on which the following chapters are developed.

Chapter two presents a discussion on the theoretical framework for learning, namely, the constructivist theory of learning. Chapter three reviews and summarises the major research findings related to the effectiveness of collaborative learning in terms of achievement, and motivation. A description of the research design and methodology is provided in chapter four, describing the selection of appropriate research tools, and the methods of data collection. The quality of the research in terms of such criteria as reliability, generalisability, validity and triangulation, is also discussed.
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Chapters five, six, seven and eight relate to analysis of data collected, documenting of results and discussion of the findings for the four sub-studies undertaken, namely Study I: Students' learning style preferences, Study II: Students' attitudes towards group-work in mathematics and the objectives for setting group work, Study III: Students' attitudes towards using computers, and Study IV: Students' concerns about group-based assessment. Chapter nine discusses the implication of all the findings, provides recommendations for future research and provides some concluding remarks.
Chapter 2

Theoretical framework for learning

2.1 Learning philosophy

The constructivist theory of learning looks at how a learner constructs knowledge from experience, which is considered unique to each individual. Constructivism is greatly influenced by Piagetian epistemology, although many also give credit to Vygotsky. Duckworth (1987, p112) defined constructivism succinctly:

*Meaning is not given to us in our encounters, but it is given by us, constructed by us, each in our own way, according to how our understanding is currently organized.*

Reacting to a period of criticism and top-down school reform efforts, educators are developing their own strategies to improve education, based on the intrinsic content of education – authentic learning, critical thinking, knowledge creation and ownership by the student, new roles for teachers, and the institution as a caring community (Elmore, 1991a; Lipman, 1991; Lieberman *et al.*, 1991; Baumann, 1991; Newmann, 1991; and Pechman, 1992). These developments have varied origins, but share a common emphasis on students’ intellectual development, and tend to be considered under the term constructivism.
I support the constructivist theory of learning to enhance mathematics learning because I believe in providing an opportunity for students to think and construct knowledge for themselves. In a constructivist learning environment, learning occurs in direct relationship to what is already known and how that prior knowledge is organised into mental models and beliefs that are used to interpret new objects and events (Gasiorowski, 1998). In other words, students in a constructivist environment interact with their surroundings as they create and internalise their own interpretations of reality according to their own experience, beliefs, and knowledge. Central to constructivism is its conception of learning. von Glasersfeld (1995, p14) argues that:

From the perspective, learning is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction.

Fosnot (1996) adds that "Rather than behaviors or skills as the goal of instruction, concept development and deep understanding are the foci" (p10). The challenge for educators is to be able to build a hypothetical model of the conceptual worlds of students, since these worlds could be very different from what is intended by the educator (von Glasersfeld, 1996).

In this paradigm, learning emphasises the process and not the product. What is vital is how one arrives at a particular answer, and not the retrieval of an 'objectively true solution'. Learning is a process of constructing meaningful representations, of making sense of one's experiential world. In this process, students' errors are seen in a positive light, and as a means of gaining insight into how they are organising their experiential world. The notion of doing something 'right' or 'correctly' is to do something that fits with "an order one has established oneself" (von Glasersfeld, 1987, P15). This perspective is consistent with the constructivist tendency to privilege multiple truths, representations, perspectives and realities.

The work of Lev Vygotsky (1962; 1978) and other developmental psychologists has become the foundation of much research and theory in developmental cognition, particularly of what has become known as social development theory. Vygotsky's theories stress the fundamental role of social interaction in the development of cognition.
(Vygotsky, 1978; Wertsch, 1985), as he believed strongly that community plays a central role in the process of 'making meaning' (Galloway, 2001).

Unlike Piaget's notion that learners' development must necessarily precede their learning, Vygotsky argued, "learning is a necessary and universal aspect of the process of developing culturally organized, specifically human psychological function" (1978, p. 90). In other words, social learning tends to precede development (Galloway, 2001). Two important principles of Vygotsky's work, More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD), together form the basis of the scaffolding component of the cognitive apprenticeship model of instruction.

Vygotsky (1978) defines the ZPD as the distance between the developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." (p86). Vygotsky believed that when a student is at the ZPD for a particular task, providing the appropriate assistance (scaffolding) will give the student enough of a 'boost' to achieve the task. Once the student, with the benefit of scaffolding, masters the task, the scaffolding can then be removed and the student will be able to complete the task again on his/her own.

Constructivism implies a kind of pedagogy where the emphasis is more on what students do than what teachers do, and where there is performance assessment of student learning rather than standardized achievement testing (Elmore, 1991b; Resnick & Klopfer, 1989; Weinberg, 1989).

In cognitive theories constructivism has many forms (Iran-Nejad, 1995). It is a specific theory of cognitive development (Piaget & Inhelder, 1970), an information processing theory of knowledge (Neisser, 1967), a way of thinking about human cognitive functioning in real-world contexts (Bartlett, 1932), a perspective on biofunctional cognition (Iran-Nejad et al., 1992), and an elaboration on one or more of these views (Weinberg, 1989; Resnick, 1987a; Sternberg, 1982).
When other views are incorporated with the theories of Piaget and Inhelder (1970), such as the popular writings of Weinberg (1989), Resnick (1987a), Sternberg (1982), and Gardner (1985), among others, there are contrasting theoretical and practical perspectives on how people learn, the nature of higher-order thinking skills, and how teachers should engage students. Therefore, in education, constructivism is much less clearly developed as any specific psychological theory.

2.2 Constructivists versus instructivists

Constructivists can be contrasted to instructivists, in that constructivists seek to create learning environments that enable students to help construct their own knowledge representations. Instructivists, on the other hand, stress that education involves a transmission of standard knowledge (Jonassen & Reeves, 1996).

According to Schifter (1996), instructivists view classrooms as places where teachers show students the procedures for getting the right answers and then monitor them as they reproduce those procedures. Instructivist-based mathematics instruction has been seen as a time-efficient method of teaching. Instructivist teachers believe that it takes less time to state a well-established method than it does to guide students to its (Gasiorowski, 1998). Constructivism, on the other hand, has been compared to the process of inventing, as it requires the progressive reorganisation of old information and the building of new information (Fosnot, 1992). Constructivists believe that students interpret novel situations as they relate to their own established structures of understanding (Schifter, 1996). According to Noddings (1990, p10), there are four beliefs that constructivists generally hold:

- All knowledge is constructed; in other words, mathematical knowledge is constructed, through a process of reflective abstraction;
- There exist cognitive structures that are activated in the process of construction;
- Cognitive structures account for construction, i.e. they explain the result of cognitive activity;
- Cognitive structures are under continual development.
It is my belief that a learning environment must be supportive of the constructivist approach in order for the approach to be effective. For instance, in a mathematics classroom, an environment that is supportive of a constructivist approach to learning, implies that students should not be expected to merely memorise facts and procedures, but rather should be supported as they go about investigating, reflecting upon new mathematical experiences and internalising new ones. According to Duffy and Jonassen (1992), instruction should focus on developing skills that will assist students in the larger context of making sense of the encountered environment.

### 2.3 Constructivism versus behaviorism

Constructivism is also often articulated in stark contrast to the behaviorist model of learning. Behavioral psychology is interested in the study of changes in manifest behaviour as opposed to changes in mental states (Murphy, 1997). Learning is conceived as a process of changing or conditioning observable behavior as the result of selective reinforcement of an individual's response to events (stimuli) that occur in the environment. The mind is seen as an empty vessel to be filled, or as a mirror reflecting reality (Murphy, 1997).

Behaviorism centres on students' efforts to accumulate knowledge of the natural world and on teachers' efforts to transmit it. It therefore relies on a transmission, instructivist approach, which is largely passive, teacher-directed and controlled. In some contexts, the term behaviorism is used synonymously with objectivism because of its reliance on an objectivist epistemology. Jonassen (1991, p28) describes the assumptions of an objectivist approach to learning:

"Objectivists believe in the existence of reliable knowledge about the world. As learners, the goal is to gain this knowledge; as educators, to transmit it. Objectivism further assumes that learners gain the same understanding from what is transmitted (...) Learning therefore consists of assimilating that objective reality. The role of education is to help students learn about the real world. The goal of designers or teachers is to interpret events for them. Learners are told about the world and are expected to replicate its content and structure in their thinking."
This objectivist model has resulted in somewhat of a stereotyped portrayal of teaching and learning which is a widely criticised and often evoked as the target of educational reform (Murphy, 1997). While behaviorism emphasises observable, external behaviors and, as such, avoids reference to meaning, representation and thought, constructivism takes a more cognitive approach. This difference has profound implications for all aspects of a theory of learning.

The way in which knowledge is conceived and acquired, the types of knowledge, skills and activities emphasised, the role of the student and the teacher, how goals are established - all of these factors are articulated differently in the constructivist perspective. Within constructivism itself, authors, researchers and theorists articulate differently the constructivist perspective by emphasising different components (Murphy, 1997).

Nonetheless, there is some agreement on a large number of issues, for example, on the role of the teacher and student. The teacher's role is not to dispense knowledge but to provide students with opportunities and incentives to build it up (von Glasersfeld, 1996). Mayer (1996) describes teachers as 'guides', and learners as 'sense makers'. In Gergen's (1995) view, teachers are coordinators, facilitators, resource advisors, tutors or coaches. Understanding the role of the teacher in the constructivist classroom provides a useful vantage point from which to grasp how the theory impacts on practice:

"The role of the authority figure has two important components. The first is to introduce new ideas or cultural tools where necessary and to provide the support and guidance for students to make sense of these for themselves. The other is to listen and diagnose the ways in which the instructional activities are being interpreted to inform further action. Teaching from this perspective is also a learning process for the teacher."

(Driver et al., 1994, p. 11)
While the radical and social perspectives of constructivism each have their particular emphases, Ernest (1995, p485) derives a set of theoretical underpinnings common to both:

1. Knowledge as a whole is problematized, not just the learner's subjective including mathematical knowledge and logic.
2. Methodological approaches are required to be much more circumspect and reflexive because there is no "royal road" to truth or near truth.
3. The focus of concern is not just the learner's cognitions, but the learner's cognitions, beliefs, and conceptions of knowledge.
4. The focus of concern with the teacher and in teacher education is not just with the teacher's knowledge of subject matter and diagnostic skills, but with the teacher's belief, conceptions, and personal theories about subject matter, teaching, and learning.
5. Although we can tentatively come to know the knowledge of others by interpreting their language and actions through our own conceptual constructs, the others have realities that are independent of ours. Indeed, it is the realities of others along with our own realities that we strive to understand, but we can never take any of these realities as fixed.
6. An awareness of the social construction of knowledge suggests a pedagogical emphasis on discussion, collaboration, negotiation, and shared meanings (…).

The notion of doing something 'right' or 'correctly' is to do something that fits with "an order one has established oneself" (von Glasersfeld, 1987, p15). This perspective is consistent with the constructivist tendency to privilege multiple truths, representations, perspectives and realities. The concept of multiplicity has important implications for teaching and learning:

...mathematics and science are viewed as systems with models that describe how the world might be rather than how it is. These models derive their validity not from their accuracy in describing the world, but from the accuracy of any predictions which might be based on them.

(Hanley, 1994, p4)

Multiplicity is an overriding concept for constructivism. It defines, not only the epistemological and theoretical perspective but, as well, the many ways in which the theory itself can be articulated. Researchers and theorists have developed variants of
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Constructivism. Nonetheless, there are many common themes in the literature on constructivism which permit the derivation of principles, instructional models and general characteristics. The following section outlines how a constructivist epistemology and theory of learning may be expressed as or translated into a wide variety of specific characteristics or principles of constructivist learning and teaching.

2.4 Constructivism and collaboration

Collaborative group work is based on the constructivist theory of learning. The basis for collaborative learning arises from the principles presented by von Glasersfeld (1989) and Vygotsky (1978). According to the constructivist theory of learning, people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. Emphasis is given to the role of language and communication (Oates, 1998). According to Clements and Battista (1990), most traditional mathematics instruction has been based on a behaviourist view of teaching and learning.

The constructivist view of mathematics teaching is that "...no one can teach mathematics. Effective teachers are those who can stimulate students to learn mathematics" (NCTM, 1990, p34). Constructivism gives students ownership of what they learn, since learning is based on students' questions and explorations.

Constructivism promotes social and communication skills by creating a classroom environment that emphasises collaboration and exchange of ideas. Students must learn how to articulate their ideas clearly as well as to collaborate on tasks effectively by sharing in group projects. Students must therefore exchange ideas, learn to negotiate with others, and evaluate their contributions in a socially acceptable manner. Language and communication plays a critical role in a constructivist learning environment given the social context within which construction takes place (Oates, 1998). This is essential to succeed in the real world, since students will always be exposed to a variety of experiences in which they will have to collaborate, cooperate and navigate among the ideas of others. Sierpinska (1994) notes the need for effective communication in achieving understanding.
The importance of language in communication is described by Pimm (1987) who views mathematics as a language. Language plays an essential role in the formulation and expression of mathematical ideas. Unfortunately, it is seldom students’ expression of their formulation of ideas (Pimm, 1987). If mathematics is indeed viewed as a language, then it is clear that students need to practice it to become fluent, and small-group learning provides an ideal environment for such practice (Oates, 1998).

It is important to note, however, that even if the basis for collaborative learning is constructivism and the important role which language plays in this process is accepted, it is not necessarily true that collaborative groups will always serve to promote effective communication and facilitate understanding. Sierpinska (1994) cites research into small-group discussions by Curcio and Artz (1997) to support her claim that, “it is now quite clear that neither discussion or writing will automatically lead to better understanding” (1994, p67). There is also discussion in literature about factors such as off-task behaviour (that is behaviour when not working on the task at hand) and what Hagelgans et al. (1995) describe as non-productive ways in which a group can function, all of which are detrimental to effective communication and cognitive development.

2.5 Social constructivism

Social constructivism emphasises the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding (Derry, 1996; McMahon, 1997). This view is closely associated with many theories, most notably the developmental theories of Vygotsky among others (Kukla, 2000). Social constructivism is based on specific assumptions about reality, knowledge, and learning. To understand and apply models of instruction that are rooted in the perspectives of social constructivists, it is important to know the premises that underlie them (Kim, 2001):
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1. Reality: Social constructivists believe that reality is constructed through human activity. Members of a society together invent the properties of the world (Kukla, 2000). For the social constructivist, reality cannot be discovered: it does not exist prior to its social invention.

2. Knowledge: To social constructivists, knowledge is also a human product, and is socially and culturally constructed. Individuals create meaning through their interactions with each other and with the environment they live in.

3. Learning: Social constructivists view learning as a social process. It does not take place only within an individual, nor is it a passive development of behaviors that are shaped by external forces. Meaningful learning occurs when individuals are engaged in social activities.

Instructional models based on the social constructivist perspective stress the need for collaboration among learners and with practitioners in society (Lave & Wenger, 1991; McMahon, 1997). Lave and Wenger (1991) assert that a society's practical knowledge is situated in relations among practitioners, their practice, and the social organization and political economy of communities of practice. For this reason, learning should involve such knowledge and practice (Lave & Wenger, 1991; Gredler, 1997). Social constructivist approaches can include reciprocal teaching, peer collaboration, problem-based instruction, and other methods that involve learning with others (Kukla, 2000).

2.6 Bringing constructivism into the classroom

In theory, constructivism in education means that teachers will embrace a holistic way of thinking about the nature of learning, something quite apart from the methodology of direct instruction. Constructivism holds that knowledge does not have a separate existence from the physical nervous system (Iran-Nejad, 1995); it cannot exist in some complete form outside the learner and be internalised, stored, and reproduced at some later time.

One quality of a constructivist classroom is its interactive nature (Gray, 1997). Authentic student-student and student-teacher dialogue is very important in a constructivist classroom. Belenky et al. (1986) inform readers that constructivists distinguish didactic talk, when participants report experiences but no new understanding
occurs, from real talk where careful listening creates an environment within which emerging ideas can grow. Perhaps this defines the difference between teacher talk in a direct instruction classroom, and purposeful talk by students in a student-centered constructivist classroom where meaningful discussion occurs and meanings emerge. Belenky et al. (1986) explain that in "real talk", domination is absent, while reciprocity, cooperation, and collaborative involvement are prominent. Consequently, constructivist activities in the classroom that focus on speaking and listening promote not only constructivist thought but also important connections between teacher and students (Gray, 1997).

Constructivism in the classroom encounters obstacles from deeply entrenched educational theory and practice, namely, (a) autonomy of knowledge as a separate product and (b) simplification by isolation (Iran-Nejad et al., 1990; Iran-Nejad & Ortony, 1984). Both assumptions are in contrast to constructivism. Information processing theories (e.g. Neisser, 1967; Rumelhart, 1980) and behaviourism have formed the core of popular educational theory, and they justify process-product curricula for direct instruction.

In principle, learning has been viewed as essentially a matter of storing information for later recall. The typical mathematics curriculum is based on a structure where important knowledge is identified for the student to acquire, often expressed in the form of task analyses and behavioural objectives (Iran-Nejad, 1995). Within this framework, teachers impart such knowledge by breaking it down (simplification) into manageable pieces for internalization by students.

Alternatives to behavioural and cognitive theories have existed for a long time in the works of functionalists such as Dewey (1896, cited in Iran-Nejad, 1995), Angell (1904, cited in Iran-Nejad, 1995), and Bartlett (1932). The functionalist research view (a) rejects the assumption of simplification by isolation, (b) focuses on how nervous systems have evolved to function in real-world contexts, and (c) objects to the view of learning as the long-term storage of knowledge. In particular, Bartlett (1932) noted the dangers associated with the assumption of simplification by isolation and the benefits of the method of simplification by integration (Iran-Nejad et al., 1990).
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The predominant teaching model is direct instruction, meaning that the teacher's central role in the classroom is to transmit knowledge to learners and students must directly absorb information presented by the teacher (Rosenshine & Stevens, 1986; Good & Brophy, 1991). This process has been based on information processing theory (Rumelhart, 1980). The student's role is one of reception and compliance (Ausubel, 1963, 1968). In this model the teacher's performance in front of students is critical, since it involves a process of disassembling knowledge by the instructor into small bits for students to comprehend.

In the constructivist classroom it should be much different, where students, instead of the teacher, organise information, explore the learning environment, conduct learning activities, and monitor their own learning. Constructivism requires teachers to focus on depth of understanding and to assume a supporting or reflective role, while students construct meaning for themselves and engage in critical thinking and problem solving.

Much of the impetus for constructivism as an educational movement stems from a reaction to the over-reliance in classrooms on rote memorisation, which is regarded as a serious problem in education (Lipman, 1991). Many critics of education insist the most important goal of school should be to teach children how to think and solve problems. Some school curricula have been based on learner-centred constructivism to promote students who can function successfully in real-world contexts (for example Anderson & Roth, 1989; Roth, 1989).

Recognising that students master only those activities they actually practice (Anderson & Roth, 1989) – an assumption in line with constructivism as well as with rote learning and drill-and-practice philosophy – some constructivists are intent on teaching students to use scientific knowledge in the same way as adults who are scientifically cultured.

Changing students' thinking presents a unique obstacle in education. According to Walberg (1991, p.55): "Students' reasoning is often mistaken but logically consistent, confidently held, and difficult to change". Kamiloff-Smith and Inhelder (1975) reported that students are highly resistant to changing theories, even in the face of overwhelming evidence to the contrary. This implies that a detailed understanding of constructivism is
optional for successfully promoting genuine change in student thinking, but if we are to
influence thinking processes directly, we must first know how they develop.

There are other challenges that require one to delve much more deeply into
constructivism than is generally considered in education. How do we find the correct
mixture of teacher control and student freedom in learning? What kind of learning
environment provides students with a sense of ownership of their own learning?
Constructivism does not relinquish teacher control of the classroom, as is frequently
implied, and neither does a sense of ownership mean collecting students' ideas and
teaching them back to them.

For instance, Yager (1991) recommends using students' own questions or ideas to guide
the teacher's lesson: using student's thinking, experiences, and interest to drive
classroom activities; posing open-ended questions; encouraging elaboration on their
questions and responses; asking for explanations of events and situations, prediction of
consequences; and encouraging students to practice self-analysis, the collection of
evidence to support ideas, and reformulation of ideas.

Although these may be regarded as constructivist teaching behaviours, they leave intact
many of the same strategies inherent in the traditional process-product and direct
instruction models (Rosenshine & Stevens, 1986; Good & Brophy, 1991).

### 2.7 Synopsis of chapter

This chapter has outlined the constructivist theory of learning as the choice of learning
philosophy adopted in this thesis. It has defined the theory as a learning philosophy.
Following that, a discussion of constructivism versus instructivism and behaviorism was
taken up which led into social constructivism, based on the principle that collaborative
learning is a social activity.

Constructivism raises some possibilities for improving educational practice in Australia
and some questions about the way professional development has traditionally been
delivered and new curricula implemented. New curricula emphasise a holistic and
constructivist rationale, and the implementation of these new curricula necessitates that teachers make significant changes in the way they teach. In addition to understanding the constructivist philosophy upon which these new curricula are based, instructors, administrators and others involved in implementing these new curricula need to understand the kinds of changes academics need to undertake as they make the transition from more traditionalist forms of instruction to constructivist strategies as well as how they can make these changes. Generally speaking, professional and curriculum development is an evolving, personal developmental process that in itself is constructivist. This process can be greatly assisted by a supportive administrative medium that allows academics to change their own personal constructs about teaching.
Chapter 3

Review of literature

3.1 Introduction

This chapter reviews the literature on collaborative learning in face-to-face and computer-supported environments as well as literature pertaining to computer technology. Research reviewed spans across discipline areas as well as across the different levels of education, particularly high school and tertiary levels. In particular, this chapter will review both past and recent literature concerning the following aspects:

- students' preferred learning styles,
- students' views on using computer technology to learn mathematics, and
- students' opinions about collaborative learning methods.

Section two of this chapter will present literature pertaining to students' preferred learning styles. The third section reviews service teaching in Australia. The fourth section reviews the literature on using computers applications more generally, and the use of computer algebra systems (CAS) like Mathematica in particular. The fifth section reviews the literature in the areas of face-to-face collaborative learning and computer-supported collaborative learning. This section will also cover the effects of gender differences, age, migrant status and language/cultural diversity. The sixth section is an analysis of research on learning and teaching in Australasian universities.
3.2 Students' learning style preferences

The idea that students learn differently is venerable and probably had its origin with the ancient Greeks (Wratcher et al., 1997). Educators have noticed that some students prefer certain methods of learning more than others, and these dispositions – referred to as learning styles – form a student's unique learning preference. Knowledge of this can assist instructors in the planning of small group, and individualised instruction (Kemp, et al., 1998). Grasha (1996, p41) has defined learning styles as:

personal qualities that influence a students' ability to acquire information, to interact with peers and the teacher, and otherwise participate in learning experiences...

Blackmore (1996) suggested that one of the first things educators can do to assist the learning process is to be aware that there are diverse learning styles in the student population. There are probably as many ways to teach as there are to learn. Perhaps the most important thing is to be aware that people do not all experience learning in the same way (Marton & Booth, 1997). Students may have very different preferences for how, when, where and how often to learn. While many instructors are aware that different learning styles exist, the application of this knowledge is often minimal. Some instructors simply opt to utilise a wide variety of teaching activities, hoping that they will cover most student learning preferences along the way. This method, though convenient, may not be the most effective or systematic way to address student learning preferences in the classroom. Instructors also assume that teaching styles, and accompanying classroom processes, are like a 'master key' (Diaz & Cartnal, 1999) and thus appropriate for any setting.

There is not an overabundance of research in the area of learning styles. Most of the studies focus on the discovery of relationships between learning styles and specific student achievement outcomes: drop-out rate, completion rate, attitudes about learning, and predictors of high risk (Diaz & Cartnal, 1999). A useful analysis of learning styles is the Kolb Learning Style Inventory (LSI) (Kolb, 1986). Kolb's work can be traced back to that famous dictum of Confucius around 450 BC: "Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand". Kolb's LSI measures student learning style preference in two bipolar dimensions (see Figure 3.1).
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Over time, learners develop a preference for either *concrete experiences* when learning or a preference for engaging in *abstract or conceptual analyses* when acquiring skills and knowledge. They also may emphasise interests in turning theory into practice (*active experimentation*), or they may prefer to engage in reflective thinking about their experiences (*reflective observation*) (Dille & Mezack, 1991).

*Figure 3.1:* Kolb’s learning styles (adapted from Litzinger & Osif, 1992, p79)

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James and Gardner (1995) described Kolb’s LSI as a cognitive learning style mode. Cognitive processes include storage and retrieval of information in the brain and represent the learner’s ways of perceiving, thinking, problem solving and remembering.

Dille and Mezack (1991) used Kolb’s LSI to identify predictors of high risk among community college students. Successful students had lower scores on their preferences for concrete experiences than did the non-successful students. Thus, since distance learning courses can lead to social isolation, and require greater reliance on independent learning skills, students with a lesser need for the concrete experience aspects of learning may be expected to be better suited to the distance format.
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Learners in this study with higher scores on concrete experience tended to exhibit a greater sensitivity to feelings, and thus would be expected to require more interactions with peers and the instructor. Successful telecourse students also preferred to look for abstract concepts to help explain the concrete experiences associated with their learning. That is, they wanted to know 'why' certain things happened in conceptual or theoretical terms. This more abstract approach clearly favoured success in the telecourse. Dille and Mezack (1991) concluded that students who need concrete experience and are not able to think abstractly are more high-risk students in a telecourse.

Gee (1990) administered the *Canfield Learning Styles Inventory* (CLSI) and studied the impact of learning style variables in a live teleconference distance education class. The purpose of the study was to examine the influence of student learning style preference, in an on-campus versus distance education remote classroom, on student achievement in the following areas: course content, course completion rates, and attitudes about learning. Both the distance and on-campus groups were taught simultaneously by the same instructor, received identical course content, and both groups met weekly (Canfield, 1980).

Students in the distance learning class who possessed a more independent and conceptual learning style had the highest average scores in all of the student achievement areas. Those with the lowest scores in student achievement in the distance learning course had a more social and conceptual learning style. Students with both a social and applied learning style performed much better in the on-campus class. The outcomes of the Gee (1990) study suggest that successful distance education students favour an independent learning environment, while successful on-campus students show a preference for working with others. The relatively small sample of 26 students indicates that additional work is needed to further explore this relationship.

In the last three or four decades, a number of educators have proposed that teaching would be more effective if faculty members took account of differences in students' learning styles. Sarasin (1998) noted that instructors should be willing to change their teaching strategies and techniques accordingly: "[Teachers] should to ensure that their methods, materials, and resources fit the ways in which their students learn and
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"maximize the learning potential of each student" (p2). Various different conceptions of learning styles have been proposed, each with some plausibility. Probably the most widely accepted and best validated is Marton and (1976a, 1976b) 'deep processors' versus 'surface processors' based upon the levels of processing theory developed by Craik and Lockhart (1972). Deep processors think about the authors' purpose and relate a reading assignment to prior knowledge, while surface processors read with little thought.

According to McKeachie (1995), another well validated style is 'field dependent' versus 'field independent' (Witkin & Goodenough, 1981). In addition to these, there are other less well validated attempts to describe differing styles of learning. Regardless of their validity, any of these methods may have heuristic value for faculty development by drawing attention to the fact that learners differ and that we need to take account of these differences in teaching (McKeachie, 1995). Many instructors think of students as a featureless mass, many rarely vary their teaching methods, believing that the method by which they were taught is best for everyone.

McKeachie (1995) suggests that a method appropriate for the majority of students may be ineffective for other students who could learn more easily with a different approach. Methods of teaching, ways of representing information, personality characteristics of teachers - all affect learning and affect different learners differently. Thinking about learning styles can lead a teacher to think about different ways of teaching, and that is good. An effective instructor needs to vary techniques and to have a variety of teaching methods and learning activities that can be drawn upon from moment to moment or from week to week to facilitate maximum learning for as many students as possible.

There are potential undesirable side effects from the use of learning style concepts. Probably the most serious is that styles are often taken to be fixed, inherited characteristics that limit students' ability to learn in ways that do not fit their styles. Thus, some instructors draw the implication that they must match their teaching to the student's particular style, and some students who have been labelled as having a particular style feel that they can only learn from a certain kind of teaching. Combination of learning styles may be helpful to instructors who have not previously
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thought seriously about differences among students. When instructors become so committed to a particular set of learning style categories, they miss individual differences and changes over time (McKeachie, 1995).

Most of the attempts to match students with instructors have proved to have relatively little effect upon learning. It is plausible that, at least initially, trying to fit teaching to a student's learning style may be helpful. However, the important thing to remember is that what are called 'learning styles' are preferences and habits of learning that have been learned, and that everyone is capable of going beyond the particular 'style' preferred at anyone time (McKeachie et al., 1985).

Regardless of their learning 'styles', students can learn strategies that enable them to be effective when taught by methods that are not compatible with their preferred 'style' (McKeachie, 1995). To assume that one must teach to a particular learning style misses the fact that a given student may be best taught by one method early in learning and by another after the student has gained some competence. For example, anxious students need a good deal of structure when they first encounter a new instructor and new material. However, if they are to overcome their anxiety, they later need challenges that they can successfully overcome (McKeachie, 1995).

It is important for both instructors and students to realise that learners always encounter many situations that are not adapted to their own preferences. What instructors might want to consider doing is to help students develop the skills and strategies required for learning effectively from instructors who do not match the students' preferred learning 'style'. Methods of teaching learning strategies are described in Weinstein and Mayer (1986), McKeachie et al., (1985). Good teaching involves more than communicating the content of one's discipline; a good instructor also needs both to motivate students to continue learning and to teach them the skills and strategies needed for continued learning.
3.3 Service teaching in Australia

This section reports on service teaching in mathematics (or cross-disciplinary as it is otherwise known), and acknowledges the work of Wood (2003) in this section. The reason for this discussion is because of the context of this current research. The mathematics subject under investigation is one that is offered in the Engineering faculty at the University of Technology, Sydney as a core subject. It is taught by academics in the Mathematics department in the Faculty of Science.

Service teaching is of critical importance to the health of mathematics departments in Australia and New Zealand due to their financial reliance on service teaching. It is surprising, however, that there have been few published investigations of cross-disciplinary teaching of mathematics when compared with international interest (e.g., Deeds et al., 2000).

In Australia, Monro (2000) takes a long-term view with his prediction of service teaching in 2010 and paints a bleak picture. He suggests that cost cutting could force universities to provide one service course for the whole of Australia, buy a course designed in the USA, outsource to private colleges or become a subsidiary of a mega world university. Cretchley et al., (2003), on educational grounds, argue for a core curriculum for engineering mathematics in Australia and draw on the experience of the European work on curriculum design for engineering. Fuller (2003) argues that mathematics departments in Australia need to change to become more service oriented.

In a similar vein, Carter (2002) emphasises the need to meet the requirements of the serviced discipline. He argues that there is no compelling reason for service mathematics to be taught by a mathematician, so mathematicians need to attend to the needs of the client group. He suggests that specialist teaching and better, more focused resources are needed. MacGillivray (2000) also gives an overview of trends in mathematics and statistics service teaching.

Other studies have examined specific topic areas and specialised groups of students. For example, Bulmer (2002) considers service teaching of large mathematics and statistics
courses to engineering students. His paper outlines the development and trial of simulations of real world applications, such as virtual rat experiments and virtual plants. Blyth et al., (2002) describe the use of the computer algebra system Maple in a matrix course. Student evaluation of the teaching was carried out using Galbraith and Haines's (2000) questionnaire. The sample was small (n = 37) and the responses neutral. The authors will investigate further refinements to the teaching and the questionnaire. Belward (2002) establishes the need for change in teaching mathematics to other disciplines. Nevertheless he feels the tensions between the need for rigour – 'remain true to one's subject' - and intuition. He has a nice example of examining how numerical algorithms behave. There were no student evaluations.

Britton (2002) also considers the relationship of mathematical knowledge to other disciplines (physics, microbiology and computer science) the main client groups of the mathematics department. There were significant problems with terminology, notation and imprecise use of mathematics by the other disciplines. Results showed that students who performed best on the decontextualised mathematics questions appeared to be able to skills better to the questions in context. This paper emphasises the need for communication with other disciplines and the important influence of small effects, such as notation, that can confuse learners. Chick (2000) investigated the skills of 32 students in a first-year service mathematics subject. These students were given data and asked to make sense of it. There was very little use of previously learned techniques from high school. This is an interesting area that needs further investigation.

Klymchuk and Gruenwald (2002) used the ideas of cognitive conflict to promote deeper understanding in their first-year engineering mathematics students. They required that students find counterexamples to statements based on common misconceptions. They asserted that this developed critical thinking skills and it appeared to be effective for the students surveyed. Several student comments are given. While this method is well known, it is important that student reactions to the introduction of strategies to improve student learning are undertaken.

Pemberton (2002b) gives a personal view of introducing the computer algebra system Maple into a large first-year mixed-discipline course of around 600 students. He
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outlines his course and discusses the timing of computer laboratories and problems faced. Varsavsky (2002) looks at the development of numeracy skills of non-mathematics major science students. She uses text-based online activities to help students to work consistently and learn from each other. The materials were designed to help address the problems of disengagement from university life, which is related to high rates of attrition and failure. Evaluation of the online activities was by online feedback, fortnightly interviews and focus groups.

Sugden (2001) believes that it is important to relate fundamental mathematical principles to practical computing realities for students whose primary consideration is not mathematics. He has devised a course to teach the principle of mathematical induction in a discrete mathematics course for information technology students. He uses Excel to support the inductive proof investigations. Student response was extremely positive.

Petocz and Reid (2003b) examine statistics as a professional tool in engineering from the point of view of the student. They present an extensive literature survey about developing professional skills. In an investigation of cross-faculty teaching and learning, Kirkup et al., (2003a, 2003b) and Wood et al., (2003), investigated the provision of mathematics (including statistics) and physics to engineering and business students. Students' opinions of their subjects were explored using focus groups and an analysis of open-ended questions from subject feedback surveys. Deans and academic staff at several Australian and UK universities were interviewed and a literature search was done. The study shows the ad hoc nature of most service teaching and the difficulties of communication across disciplinary boundaries especially where there are resource implications. The papers recommend ways to improve the quality of service teaching.

3.4 Computer-based technology

Some educators are working towards changing the content of the mathematics curricula in universities and the ways in which it is taught in order to best prepare students for the 'real world', by moving from a focus on arithmetic and computational skills toward a
curriculum that develops students' abilities to think, reason, and communicate mathematically (Petocz & Reid, 2005; Burton, 2004).

Their goal is to help students construct their conceptual understanding of mathematics, not just memorise facts and rules. Likewise, the teaching of mathematics is changing in order to meet these new goals. Instead of teaching by demonstration, a blend of instructional methodologies is being used that include individual and group work and direct instruction. The aim is to provide frequent opportunities for students to explore and solve problems, individually and with others, and to develop their mathematical skills in the context of this exploration (Stacey et al., 2002).

Lecturers can be facilitators of learning, guiding students' explorations, asking questions that extend their thinking, and encouraging students to communicate their thinking. One catalyst for change in teaching methods is the widespread and increasing use of computer algebra systems by professional mathematicians and in teaching and learning mathematics. According to the Panel on Educational Technology of the Committee of Advisors on Science and Technology (1997, pi), there are two key requirements for the use of technology in education today:

- Focus on learning with technology, not about technology, and
- Emphasise content and pedagogy, not just hardware... Particular attention should be given to the potential role of technology in achieving the goals of current educational reform efforts through the use of new pedagogic methods focusing on the development of higher order reasoning and problem-solving skills.

Universities that are moving towards an educational approach that incorporates the impact of technology and the flexible needs of learners, endeavour to make the student the central focus in the design and development of learning opportunities (Engelbrecht & Harding, 2005). The use of computer-based instruction has changed teaching methods dramatically as current technologies have evolved (Hannafin, 1992). Technology-rich settings now encourage the use of relevant real-life contexts where students are encouraged to think critically during mathematical problem-solving activities. Hannafin (1992, p58) states that:
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Rather than being taught the reasoning skills in a directive manner, students investigate alternatives and determine information requirements. Students generate plans, identify knowledge requirements, test their plans, and revise them as needed to solve the problem.

The impact of computer technology on how and what students learn and what instructors teach has lagged behind its influence on manufacturing, product development, and sales (D’Souza, 2002). In many classrooms, students continue to be drilled on the possession of information and the development of competence in the performance of algorithmic manipulations. Although appropriate levels of factual knowledge and skill are important outcomes, what students also need is a sound understanding of concepts and the ability to use knowledge in new and often unexpected ways.

The introduction of technology into mathematics instruction raises new possibilities for teaching and understanding mathematics. The calculator, graphics calculator and computer are among the technological innovations that have potential for dramatic impacts on the teaching and learning of tertiary mathematics. For instance, the study of domain, range, inverses, geometric transformations, solutions to equations, inequalities, systems of equations and their applications can be accomplished more effectively using a technological approach (Neyland, 1994). Powerful geometric representations of problem situations can be easily added to the usual algebraic representations. Thus, the power of visualisation can be used to study mathematical concepts and ideas (Demana & Waits, 1990).

3.4.1 Learning from technology

When technology is used to convey specific information or skills, Zucchermaglio (1993) describes it as ‘full technology’, that is, full of information to be conveyed to the student. Maddux et al. (1997) label applications that support this use as Type I applications, which are designed to make it easier, quicker, or otherwise more efficient to continue teaching the same things in the same ways we have always taught them. The use of technology in this case mirrors traditional classroom practice, in that users are
relatively passive, the content and interaction between the user and the software are predetermined, and there is a limited repertoire of acceptable responses.

The acquisition of facts through repeated practice and rote memory, or learning from the technology (Jonassen, 1996), is the goal of instruction for this type. Full or Type I technologies include computer assisted instruction, integrated learning systems, computer-based tutoring systems, and assessment software (Boethel & Dimock, 1999). McClintock (1992) points out that technology has often been used as a replacement for existing tools, such as books, rather than as an alternative medium through which different tasks might be performed and different objectives might be achieved.

Literally hundreds of research studies have been conducted regarding the effects of computer-assisted instruction (CAI). From an analysis of twelve meta-analyses of the effectiveness of computer-based instruction programs developed primarily prior to 1990, Kulik (1994) concludes that students usually learn more and in less time with computer-based instruction. Becker (1992), however, found numerous methodological problems with many studies that have demonstrated positive effects of using CAL. In his meta-analysis of 100 studies, he concluded that differences in CAI users and non-users were too small to have educational significance.

Researchers such as Vockell and Schwartz (1992) suggest that computer-assisted instruction can increase achievement because it leads to automaticity of lower-level skills through extended practice. A computer that is endlessly patient with the student monitors this practice. In the tutorial form of computer-assisted instruction, the computer provides additional information to the student if an incorrect answer is supplied and this continues until the student is successful.

A study carried out by D'Souza et al. (2005) investigated first-year engineering students' views about the use of computer technology, in particular, computer algebra systems (CAS). They suggested that if students are to use computer technology, it is important that it be blended into their everyday class work. They must therefore be introduced to CAS in a systematic way, and they need to be required to use it as part of
their assessment. In terms of assessment, examinations must emphasise concepts, so that students see the value of learning them and can appreciate the help of CAS.

Software packages can influence behaviours such as cooperation and motivation, as well as how students interact with each other. Students are less likely to use computers in their learning if they see it simply as an add-on or as another subject to learn or simply as an aid to learn the same old curriculum (D'Souza et al., 2005). It is important to think about the experience we want students to have, the learning we want to build on, and select software carefully to encourage certain types of learning experiences. The current exploration by many researchers into the relationships between teaching, learning, computers and mathematics will help with this debate.

3.4.2 Technology as an object of/instruction

One use of technology that exemplifies traditional learning environments includes learning about the technology itself (Jonassen, 1996). Classes in computer programming and computer literacy are designed to teach students how computers work. Students learn specific skills related to using the computer, such as keyboarding skills, ethical uses of computers, or a particular programming language, but these skills are not tied to other content. These classes were prevalent in the 1980s, but Jonassen (1996) observed that this use of technology was less emphasised by them. He attributes the change to the:

- increasing availability of computers, which gives students more experience with them outside class;
- understanding that one does not have to know how a computer works to take advantage of it as a tool; and
- emphasis on memorising vocabulary about computers in computer literacy classes, which has little relevance to the educational goals of schools.

Learning with technology drives much of the current thinking about the use of technology to support learning (Jonassen, 1996). Bonk et al. (1996, p95) note that, "currently popular ideas about students using electronic tools to be designers of knowledge are akin to Dewey's arguments that children must actively construct and interrelate knowledge by learning in more authentic ways".

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According to this perspective, when technology becomes an essential part of the classroom learning environment it provides a tool for both instructors and students that can facilitate new roles and new instructional strategies. Technology used as a tool can serve as a means to seek and process information, and to reflect on one’s understandings, beliefs, and thinking processes. Technology used in this way allows students to enter information and explore new content relationships (Zucchermaglio, 1993).

Ordinary application software such as word-processing, spreadsheet, graphics, presentation, and database software; problem-solving software; simulations; electronic mail; and the Internet are technology tools that fit into this category. These applications, labelled Type 11 by Maddux et al. (1997), give students control of almost everything that happens, including the interaction between themselves and the machine. Rather than rote memorisation of facts, Type 11 applications encourage the accomplishment of creative, higher-level tasks (Maddux et al., 1997). Due to the interactive nature of technology and the power of its information-processing capabilities, Jonassen (1996) proposes that when students learn with technology, it becomes a mindtool. He defines mindtools as: "computer based tools and learning environments that have been adapted or developed to function as intellectual partners with the learner in order to engage and facilitate critical thinking and higher-order learning" (Jonassen, 1996, p.9).

3.4.3 Role of computers in tertiary mathematics

Researchers such as Taylor (1981) and Kissane (1989) suggest four ways in which computers are used in education (in Goos & Cretchley, 2003):

1. as a tutor – the computer environment provides instruction on some topic (for example computer assisted instruction);
2. as a tutee – the learner takes an active part in programming the computer and learns something about non-computer oriented content as a result (for example, Logo and related software);
3. as a tool – the software allows students to perform complex or time consuming tasks that would not otherwise be possible, or would have to be carried out in some other way.
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4. as a catalyst - provoking mathematical explorations and discussion or invoking the use of problem-solving strategies.

The fourth category views computers as catalysts for visualisation, higher order thinking, and collaboration (Goos & Cretchley, 2003). I will discuss the role of computers in tertiary mathematics learning - computer as a tutor, tool and catalyst.

Computer as a tutor – Monson and Judd (2001) describe an interactive system that can be used for practice and assessment of routine exercises on topics in calculus, linear algebra and statistics that included diagnostic feedback on incorrect answers arising from a wide range of typical errors. While students report positively on the use of such a system to keep them to a learning schedule, the nature of students' learning outcomes is yet to be established, and the authors draw attention to the danger of using such a package as a replacement for teaching, rather than a supplement or aid. A study by Pierce and Atkinson (2003) looked at students who viewed a computer animation on the concept of the derivative and were then required to design worksheets for learning that concept. The study revealed that some students' preference for algebraic methods was so strong that their worksheets were little influenced by the clearly graphical nature of the animation.

Computer as a tool and catalyst - Computers are widely used for communication between staff and students at the tertiary level, and hence are an increasingly accessible medium also for learning (Goos & Cretchley, 2003). Other factors supporting computer use include decreasing cost of software, and the demand from employees for graduates with appropriate computer skills and software knowledge for their field. Scientific software and spreadsheet packages are powerful vehicles for calculation, visualisation, and exploration (Goos & Cretchley, 2003). For science and engineering students, tertiary educators favour software packages such as Maple, MATLAB, and Mathematica. As Goos and Cretchley (2003, p156) states, three levels of investigation are discernable in current literature on the use of software as a tool or catalyst at the tertiary level:
1. Reports on the introduction of a technology initiative and its early use centre on perceptions of the objectives and effects of the initiative, with methodology based largely on custom-designed questionnaire and interviews.

2. Deeper questions and repeated trials mark the next level, accompanied by more thoughtful research design, and refinement of methodology and instruments. Valuable comparisons of findings across different studies are emerging from this research, lending coherence to the body of literature.

3. Reflecting a desire for understanding of questions that arise in new learning environments and cultures, finer studies of particular cognitive and affective issues are emerging, driven by educators who are becoming experienced with using technology for learning.

A significant expression of the need for more careful design of studies and a highly positive trend for the future of research in this area, is the partnership that university mathematics lecturers are seeking with education specialists, in order to investigate issues appropriately (see Blyth et al., 2002; Cretchley & Galbraith, 2002; Cretchley et al., 2001; Fogarty et al., 2001; Galbraith & Pemberton, 2002; Pierce & Stacey, 2002).

### 3.4.4 Advantages of computer-based

The following are advantages that advocates for technology propose as significant, each of which is discussed separately below:

- Exploration and independent inquiry
- Shared knowledge and collaborative learning
- Efficiency and organisation
- Analysing and studying information

**Exploration and independent inquiry**

Technology can support exploration, which helps students set achievable goals, form and test hypotheses, and make discoveries of their own (Collins, 1990). As Means and Olson (1995) remarked, students are free to roam around the information and discover answers to personal inquiries. With appropriate instructor guidance, such exploration promotes higher-order thinking skills and helps students contend with open-ended questions, the kind of questions they will encounter in their own lives after school.
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Research studies such as those carried out by Gregoire et al. (1996); Heidmann et al. (1996); and Kendall and Broihier (1992), which focused on technology and students' motivation to learn, relied on self-reports of students' attitudes toward computers and found, in general, that most students considered computer activities to be highly motivating and interesting.

- **Shared knowledge and collaborative learning**

Using technology to support collaborative knowledge integration requires tools that enable group thinking, problem-solving, and task orientation. Sharing data also offers the opportunity to share with a wider and more authentic audience. The goal is to help students develop community knowledge bases and expertise instead of focusing only on individual student learning. Shared data leads to larger and more accurate data sets. Sharing real data from primary sources with experts leads to students thinking and working the way experts think and work (Evard, 1996; Federman & Edwards, 1997; Jonassen & Reeves, 1996; Lonergan, 1997; Scardamalia & Bereiter, 1991; Wideman & Owston, 1993).

- **Efficiency and organisation**

Jonassen and Reeves (1996) suggests that the speed with which students can access information is a feature that can promote habits of efficiency and organisation. Students can go to the Internet in the classroom and locate information rather than making a trip to the library. Search strategies can help them clarify their questions, and once they have found a potential site, they can evaluate the information for its validity, appropriateness, and perspective. They can then organise and analyse the data using mapping software or spreadsheets and organise their thoughts, using a word processor for instance. Project management software helps students identify and complete tasks for a project, and instructional management systems can help teachers keep track of student data, thus increasing the efficiency of instruction (D'Souza, 2002).

- **Analysing and studying information**

Technology can become a powerful tool for assembling, modifying, assessing, and studying information (Strommen & Lincoln, 1992). Modelling software represents a strategy that makes expert solutions visible and tacit knowledge explicit (Collins, 1990).
Using technology as a tool can aid learning by requiring students to analyse the underlying structure of ideas they are studying. Authentic data sets and thinking about and formulating explanations can foster the generation of new knowledge and deep understanding (Dede et al., 1997). Computing power makes it possible to create and manipulate authentic data with scientific probes and graphing software or to manipulate large databases, such as census data, to seek answers to complex questions.

3.4.5 Research Findings on the use of technology

Despite the relatively low number of quantitative studies showing measurable changes in mathematics learning due to technology, the wider educational field of literature suggests major positive benefits. Of note are the American-based reports by Software Publishers Association (1997) and Cradler and Bridgforth (1998). Sharing a common focus and approach, both reports reviewed well over 100 studies completed in the United States on the effectiveness of educational technology, some of which were comparative in nature. Conclusions of particular relevance to this study are summarised here:

- Educational technology demonstrates positive effects on achievement. However, the effectiveness of such technology tends to vary as a function of the curriculum content and software design.
- The use of educational technology leads to improvement in attitudes and motivation towards learning, especially for 'at risk' (lower ability) students.
- The introduction of technology into the learning environment increases student-centered learning, encourages cooperative learning, and stimulates student-teacher interaction. In general, these major reports portray a highly positive outlook to the effective use of technology in education.

Coupland (2004) used a theoretical framework derived from activity theory to investigate the introduction of computer algebra systems in first year university mathematics subjects. Both qualitative and quantitative data were collected from approximately one hundred students and two academics, and then analysed using a range of methods. The major question for this study was: What are the socio-cultural
dynamics of learning with a new tool? The main findings included the identification of the critical nature of purpose.

Coupland (2004) proposes that personal identity as a learner of mathematics is constructed through choosing to engage at surface or deep levels, alone or with others. Students with a low level of computing background who had a high level of engagement and sense of purpose in their mathematical learning reported that they appropriated the new tool for their own personal use. Students with a high level of computing experience who were unable to form goals congruent with the learning tasks were less likely to appropriate the tool.

• **Effects on achievement and motivation**

Kulik's (1994) meta-analyses of 500 individual research studies of computer-based instruction (CHI) showed that, on average, students who used CHI scored at the 64th percentile on tests of achievement compared to students in the control conditions without computers who scored at the 50th percentile. He found that students learnt more in less time when they received computer-based instruction and that students liked their classes more and developed more positive attitudes when classes included computer-based instruction.

Sivin-Kachala (1998) reviewed 219 research projects from 1990 to 1997 to assess the effect of technology on learning and achievement across all learning domains and all ages of students. From his analysis, he reported that students in technology rich environments experienced positive effects on achievement in all major subject areas; students in technology-rich environments showed increased achievement in preschool through higher education; and students' attitudes toward learning and their own self-concept improved consistently when computers were used for instruction. However, what was inconclusive was whether the specific student population, the software design, the educator's role, and/or the level of student access to the technology influenced the level of effectiveness of educational outcomes.

These studies have shown that students with access to either computer-assisted instruction; or integrated learning systems technology; or simulations and software that
teaches higher order thinking show positive gains on standardised tests and national tests.

Student motivation is an important factor for many educators. However, the research on student motivation appears to be inconclusive, since several of the studies contradict one another. Some studies have found that student use of technology significantly increased student motivation over time (Frear & Hirschbuhl, 1999; Isernhagen, 1999; Liao, 1998; Middleton & Murray, 1999). Yet Hecht and Roberts (1996) found that although student gains were greater in the technology-based classroom than in the traditional classroom, the differences were not statistically significant.

A group of educators in Nebraska identified technology as the major catalyst for encouraging students to interact with the content (Isernhagen, 1999). Yet technology alone is not the answer to the complex problem of motivating learners (Mellon, 1999). A major problem with technology research is the lack of studies dealing with student motivation and attitude (Frear & Hirschbuhl, 1999).

- **Gender differences**

This section looks at research conducted in the area of gender and technology at the school level. The role of education in creating performance differences on the basis of gender have been the source of considerable controversy in schools and in the popular and professional literature about education (Bain et al., 1999). Concerns exist regarding the extent to which the differences identified in the 1970's and 1980's associated with the achievement of women in mathematics (Shashaani, 1995) are recurring in the area of information technology.

According to Mangione (1995), peer pressure, male metaphors in the design of information technology, and gender bias in software may be creating an educational "deja-vu" with potentially devastating effects on the opportunities for female students. Lee (1995), using a qualitative analysis, observed clear differences in attitudes and confidence between male and female students who used computers in secondary mathematics. These differences included the following findings:
Boys showed a greater willingness to experiment with the software, exploring all the tools to the detriment of task focus;

Boys tended to work independently and competitively whereas girls preferred to work cooperatively and were very self critical, requiring more positive encouragement, and were more inventive with the tasks;

Girls frequently attempted ideas that were specifically related to the task and maintained task focus;

Girls were much more particular about the appearance of their work;

Despite these previous studies that have tended to support the belief that males are more successful with computers and mathematics than are females, Bennett (1992) concludes that sex bias may have been disappearing, or perhaps never existed. Similarly, Cloke (1996) found no significant gender differences with secondary school students, suggesting that differences may decrease with familiarity and age.

Although it appeared that the male students in Lee's (1995) study were using the computer to advantage, the resulting work suggested that the girls demonstrated a greater depth of mathematical understanding. The difference observed by Lee (1995) is possibly best described in terms of approach. Research suggests that girls do not approach computers with the same enthusiasm as boys and may not perceive the same advantages (Jones, 1997). In particular, an apparent difference in preferred learning styles might require teachers to provide a more supportive and collaborative environment for girls.

Rowe (1993) pointed out systematic gender differences in the use of computers in the classroom, where "... girls are often not given appropriate support and contexts for learning about and with computers" (p. 238). The gender differences in computer use are more evident at the secondary level than in the elementary years (Hattie & Fitzgerald, 1988, cited in Rowe, 1993).

According to Rowe (1993), "computers are tools which can be used for a variety of purposes. However, in the absence of a broader perspective, many schools subsume them under mathematics/science curricula, and thus they take on an existing stigma of
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sex stereotypes" (p257). As Cheek and Agruso (1995) stated, "available research suggests that widespread use of these [computer] technological tools raises significant issues for females and underrepresented populations in mathematics, science and technology fields" (p75). Nevertheless, as reported in Rowe (1993), when asked "which subjects do you not like as much as you used to, now that you are using a computer?", 30% of the girls and 12% of the boys said mathematics, while only 11% of the girls said science compared to 30% of the boys (p255). According to Rockman (cited in Branscum, 1992, p88), "we should start exploring ways to achieve equity using technology". In this context, how the gender differences in mathematics education may affect computer-based learning is a question that needs to be explored.

3.4.6 Technology as a way of supporting students' learning

At the university level the introduction of technologies has been seen by some as a means to renew pedagogical practices, and to avoid a style of teaching that was too formal or too algorithmic. A potential advantage is it was intended to create better coherence between teaching practice and the constructivist approach to learning. Hoyles (1999 cited in King et al., 2003, p350) in her description of the potential contribution to post-secondary education of research carried out at the secondary level, has emphasised that:

There is considerable evidence of the computer's potential to:

1. Foster more active learning using experimental approaches along with the possibility of helping students to forge connections between different forms of expression;
2. Provoke constructionist approaches to learning mathematics where students learn by building, debugging and reflection, with the result that the structure of mathematics and the ways the pieces fit together are open to inspection;
3. Motivate explanations in the face of 'surprising' feedback, that is, start a process of argumentation which is connected to formal proof;
4. Foster cooperative work, encouraging discussion of different solutions and strategies; computer work is more visible and more easily 'conveyed' between lecturer and students;
5. Open a window on to student thought processes - students hold different conceptions of mathematical ideas which are hard to access, even in the case of articulate skills. How students interact with the computer and respond to feedback can give insight into their conceptions and their beliefs about mathematics and the role of computers.
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Regarding necessary skills and concepts that students must possess before they can use a powerful technological tool, Hillel (2003) suggests seizing the 'black box' feature as a learning opportunity which according to Noss (1999) is a pedagogical choice, a kind of 'didactical inversion' which is made within the larger context of the instructor's course design (Kent & Noss, 1999; Noss, 1999). Hoyles (1999) added that a successful integration of computers necessitates the rethinking of the content and sequence of mathematics courses given that students and mathematics have (or should have) changed in the light of the new technology, as well as teaching approaches to take into account the broad range of responses inevitable in interacting with computers and the relationship of 'computer mathematics' to pen-and-paper mathematics.

3.4.7 Using computer algebra systems

Computer Algebra Systems (CAS) have been recognised as highly valuable for doing mathematics and potentially valuable for teaching and learning mathematics. However, the mere presence of CAS in a classroom does not mean that its potential benefits will be realised. Students must learn to use both hardware and software effectively and academics need to develop appropriate learning tasks. Artigue (2001) calls this process, by which such available technology becomes a powerful tool, 'instrumental genesis'. This learning process presents a new, additional challenge for students. Atkins et al., (1995) expressed concern that students learning new mathematics with new technology may be distracted by the overhead of learning to use the technology. In order to benefit from the availability of CAS, students must not only be able but also willing and discriminating in their use of this new technology.

Arnold (1995) observed that the participants in his study showed a range of levels of engagement with the technology. He found that students' use of the software was sometimes impeded by their beliefs about mathematics and their perceptions of what was valuable. Lagrange (1996) also commented that in his experience not all students wanted to use CAS. They did not want to be relieved of pen and paper work and that many, in fact, enjoyed doing routine calculations (Pierce & Stacey, 2002).

Students' success in benefiting from the use of CAS will depend on how effectively they learn to use this technology. The efficacy of their use will depend on both technical
and personal aspects: whether the student can operate the program with a minimum of
difficulty; and their attitudes towards the use of CAS.

The availability of computer algebra systems has generated discussion and debate about
mathematics content and teaching practices at the secondary and tertiary levels (Forster
\textit{et al.}, 2003). Computers can be used to change mathematics teaching by decreasing the
time needed for procedural skills and increasing the time for conceptual understanding,
the importance of which has been realised by many researchers (Kadijevich &
Haapasalo, 2001). In many cases, a concept relies on a procedure, or vice versa. For
example, the fact that a system of linear equations has an infinite number of solutions
relies on a procedure confirming that one of its equations is equal to a linear
combination of the others. The fact that a correct (equivalent) transformation is applied
to the given algebraic entity relies on some conceptual knowledge regarding the
domains of the underlying functions.

Although mathematics education should ideally develop both procedural and conceptual
and make links between the only a few computer-assisted learning
(CAL) studies have examined the effects regarding the coordination of procedural and
conceptual mathematical knowledge. Kadijevich and Haapasalo (2001) show that links
between the two knowledge types (Procedural-Conceptual (P-C) links) can be
established through learning activities requiring the production and use of rules as well
as multiple representations.

A study by Ball (2002) reported on students' practices within a CAS environment. A
rubric titled \textit{Reasons, Information, Plan and Answers} (Ball & Stacey, 2003) was
designed to assist students to communicate their mathematical thinking in written form.
It recognized that communication practices in CAS and non-CAS environments could
be different, particularly concerning the emphasis that is placed on solution planning
and supportive reasoning. Ball (2002) introduced the rubric to two Year 12 classes (n =
35) and analysed the solutions to a worded quadratic problem. Students were requested
to document intermediate steps to the solution and indicate CAS use. Written solutions
showed that students employed a mixture of by-hand and by-CAS techniques. Some
students included reasons and solution plans. However, the results of the study
highlighted that communicating effectively when doing, learning or teaching mathematics with CAS is a challenge for staff and students.

Computer algebra systems challenge the traditional mathematics curriculum with many questions. For instance, what will be the place of memorising algorithms in the future? Can the mathematics curriculum be broadened to include more generic skills such as mathematical modelling if CAS are used to perform the algebra and calculus manipulations? What is the role of assessment in the future mathematics curriculum (Wood & D'Souza, 2003)? These are just a few of the issues that mathematics instructors have to consider.

3.4.8 Further research

The lack of a credible body of research is in part a result of the rapid change in educational practice and technology development over the past decade. In terms of technology, software older than five years is generally considered obsolete. Therefore, research based on old technology is generally less applicable or relevant to current classroom practice. Of further concern, Kissane (1995) states that the context in which research is located may be critical to the relevance of the research. Thus, research relevant to tertiary level mathematics should be carried out with typical tertiary students at regular intervals.

However, finding a natural setting conducive for research within which technology is not a novelty is rare. The introduction of novel activities into the classroom may result in the Hawthorn Effect, biasing results (McCoy, 1991). Rowe (1996) elaborates further on the importance of context and research validity by arguing for a need for change in research approach. The introduction of computers becomes inextricably intertwined with the learning process and changes the learning context as a whole. If this view is accepted, valid evaluations of the effects of computers in the classroom require a systematic approach by conceptualising the learning environment as a cluster of variables that jointly affect the gains or losses of technology in education (Rowe, 1996).
3.5 Collaborative learning

Cooperative learning is generally understood to be learning that takes place in an environment where students in small groups share ideas and work collaboratively to complete academic tasks. However, such a general definition overlooks the fact that there are actually a number of different models for cooperative learning, models that vary considerably in their assumptions about the nature of learning and about the roles of teachers and students in the classroom.


Researchers like Johnson and Johnson (1990) and Davidson (1990a) do not see the need to distinguish between the terms cooperative learning, collaborative learning and small-group learning. They view these terminologies collectively, as a generic term for learning involving various types of small-group interactive instructional procedures.

On the other hand, researchers like Panitz (1996) and Hagelgans et al. (1995) view them as distinct concepts requiring precise definitions. In any case, most researchers agree on the need to define exactly what is meant when referring to one of these learning strategies, regardless of which viewpoint is taken (Oates, 1998). As far as this research study goes, no distinctions are made between the terms collaborative learning, cooperative learning or small-group learning as I have elected to follow the position of Johnson and Johnson (1990) and Davidson (1990a). Hence each of these terms will be used interchangeably in this thesis.

Although considerable evidence exists to support the claim that collaborative learning promotes achievement as well as other positive affective outcomes at the school levels, few studies have examined the effects of cooperative learning at tertiary levels (Slavin, 1985; 1991). Collaborative learning is an area that is under-utilised in mathematics teaching and learning at university level (Wood, 2003). She suggests that we need to investigate this carefully to examine optimal implementation. Hence, this investigation aims to help address this gap in the research by attempting to investigate the effects of collaborative learning on students' attitudes in the undergraduate mathematics classroom.
There has been a growing interest among researchers in cooperative learning and it is being accepted as an important teaching methodology (Cohen, 1994). International associations, such as the International Association for the Study of Cooperation in Education (IASCE), have been formed to provide a forum for researchers and educationalists to share ideas about cooperation in education (Slavin, 1985).

The use of cooperative learning in mathematics classrooms is a related area that has also attracted considerable interest (Davidson & Knoll, 1991). The research literature on collaborative learning is not easy to assess and synthesise. This is because studies conducted in this field have a diversity of aims, subject matter, topics, education levels and study designs. Several attempts have been made to synthesise this overwhelming volume of literature. However, often these literature reviews have been very broad in scope and therefore are unlikely to provide instructors with the specific information required for restructuring their classrooms or curricula. A need therefore arises to synthesise that subset of literature, which may interest tertiary educators. Research findings emphasise the academic benefits of using collaborative learning strategies. However, the number of studies focusing on mathematics achievement at the tertiary level is sparse relative to the number of studies at elementary and high school levels.

3.5.1 Overview of collaborative learning

The learning of mathematics is often viewed as an isolated, individualistic matter wherein one sits alone with pen-and-paper and struggles to understand the material and concepts at hand. This process can often be quite lonely and frustrating. It is therefore not surprising that many students are afraid of mathematics. They believe that only a few talented individuals can successfully compete in the mathematical realm (D'Souza & Wood, 2003e).

Despite support for acceptance of collaborative learning by many researchers and educational organisations, this strategy is not frequently used at universities. A closer look at past literature shows that collaborative learning is more often used in subject areas like English than in mathematics (D'Souza & Wood, 2003e).
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Much of the recent research in mathematics education has increasingly focused on re-assessing conceptualising mathematics teaching and learning (Lampert, 1990). Informed by theories concerning the social context of learning and development, researchers have argued that learning mathematics involves participating in the activities of a 'community of practice', whose identity is forged by the adoption of the language conventions and ways of thinking valued by the wider community of mathematicians (D'Souza & Wood, 2003e).

In 'community of practice' classrooms, students take on new roles that contrast sharply with those allowed within settings that are more traditional. In traditional classrooms, mathematics is usually presented as abstract knowledge already discovered by experts, with the instructor as the sole source of knowledge and authority and students as the passive consumers of knowledge. By comparison, in community of practice classrooms, mathematical knowledge is constructed and tested by students as they work collaboratively under the guidance of the teacher. Student participation is therefore expanded to include discussion with peers in order to solve problems and assess their understanding (Goos & Galbraith, 1996).

Small-group collaborative learning provides an alternative to both traditional whole-class expository instruction and individual instruction systems. This method of learning can be applied with all age levels of students, all levels of the mathematics curriculum, and all major topic areas in mathematics.

3.5.2 Comparing learning styles

D'Souza and Wood (2003d) looked at the rationale for setting group work in first-year engineering mathematics in an Australian university. Collaborative learning can be contrasted with competitive learning and individualistic learning. When mathematics lessons are structured competitively, students work against each other to determine who is best. Students are graded on a curve, which requires them to work faster and more accurately than their peers. In an individualistic lesson, students work by themselves at their own speed to accomplish learning goals unrelated to those of their classmates. Individual goals are assigned each day, students' efforts are evaluated on a set of
standards, and rewards are given accordingly (Johnson & Johnson, 1989). Collaborative learning is one of an alternative range of approaches, based on the premises that:

1. each student has an individual thinking style that needs to be identified and used;
2. individual thoughtful concentration and knowledge construction are important components of the learning and problem-solving process;
3. the learning and problem-solving process is enhanced when individuals pool in their ideas, challenge and elaborate on each other’s thinking.

(Neyland, 1994, p35)

In a collaborative learning situation, students' achievements of their goals are positively correlated, that is, students perceive that they can reach their learning goals if and only if the other students in the learning group also reach their goals. Thus, students seek outcomes that are beneficial to all group members (Johnson & Johnson, 1989). Groups can achieve a level of efficiency unavailable to individuals, by sharing out components of complex tasks. Collaborative approaches provide opportunities for more sharing of decision-making responsibilities between the students, thus giving them more autonomy and control.

3.5.3 Benefits of collaborative learning

Numerous studies have reported many benefits of collaborative learning. The benefits fall into three categories – academic benefits, social benefits and psychological benefits. An analysis of the drawbacks of using collaborative learning techniques will not be discussed. However, I will discuss some negative aspects of group work such as assessment in later chapters. Some of the research on the benefits of using collaborative learning methods is dated, but a study by D’Souza and Wood (2003e) helped bridge that gap by using the themes emerging from previous research literature and substantiating them by research with engineering students who were studying a core first year mathematics subject, about their opinions regarding group work.

Academically, a number of potential benefits have been suggested for collaborative learning such as that it:

a. develops higher level thinking skills (Webb, 1982);
b. stimulates critical thinking and helps students clarify ideas through discussion and debate (Johnson, 1973; 1974a);
c. develops oral communication skills (Yager et al., 1985a);
d. fosters metacognition in students (O'Donnell & Dansereau, 1992);
e. creates an environment of active, involved, exploratory learning (Slavin, 1990);
f. involves students in developing curriculum and class procedures (Kort, 1992);
g. promotes a learning goal rather than a performance goal (Panitz & Panitz, 1998);
h. allows students to exercise a sense of control on task (Sharan & Sharan, 1976);
i. promotes higher achievement and class attendance (Hagman & Hayes, 1986);
j. promotes and increases student retention (Astin, 1977);
k. enhances self-management skills (Resnick, 1987a);
l. promotes innovation in teaching and classroom techniques (Slavin, 1980; 1990);
m. fosters modelling of problem solving techniques by students' peers (Schunk & Hanson, 1985);
n. addresses learning style differences among students (Midkiff & Thomasson, 1993).

Socially, benefits for collaborative learning include the way that it promotes:

a. student-faculty interaction and familiarity (Cooper et al., 1984);
b. develops social interaction skills (Johnson et al., 1984);
c. promotes positive societal responses to problems and fosters a supportive environment within which to manage conflict resolution (Johnson & Johnson, 1990);
d. creates a stronger social support system (Cohen & Willis, 1985);
e. fosters develops interpersonal relationships (Johnson & Johnson, 1987);
f. builds more positive heterogeneous relationships (Webb, 1980);
g. encourages diversity understanding (Burnstein & McRae, 1962);
h. fosters a greater ability in students to view situations from others' perspectives (development of empathy) (Yager et al., 1985b);
i. establishes an atmosphere of cooperation and helping school wide (Deutsch, 1985);
j. fosters team building and a team approach to problem solving while maintaining individual accountability (Cooper et al., 1984; Johnson et al., 1984);
k. creates environments where students can practice building leadership skills (Johnson & Johnson, 1990; Bean, 1996);
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1. increases leadership skills of female students (Bean, 1996);
2. provides the foundation for developing learning communities within institutions and in courses (Tinto, 1997);
3. helps teachers change their roles from their being the focus of the teaching process to becoming facilitators of the learning process. They move from teacher-centered to student-centered learning (Hertz-Lazarowitz et al., 1992).

Psychologically, collaborative learning can:

a. build self-esteem in students (Johnson & Johnson, 1989);
b. enhance student satisfaction with the learning experience (Panitz & Panitz, 1998);
c. promote a mastery attribution pattern rather than helpless attribution pattern (Panitz & Panitz, 1998);
d. encourage students to seek help and accept tutoring from their peers (Hertz-Lazarowitz et al., 1992);
e. significantly reduce classroom anxiety (Kessler et al., 1985); and reduce test anxiety (Johnson & Johnson, 1989).

3.5.4 Collaborative learning in face-to-face and computer-mediated environments

If mathematics instruction is to help students think mathematically, understand the connections among various mathematical facts and procedures, and be able to apply formal mathematical knowledge flexibly and meaningfully, then cooperative learning can assist in mathematics classes in several ways. Davidson (1990a) posits that:

• Mathematical concepts and skills are best learned as a dynamic process with the active engagement of students.
• Mathematical problem solving is an interpersonal enterprise.
• Mathematics learning groups have to be structured cooperatively to communicate effectively.
• Cooperation promotes higher achievement in mathematics than competitive and individualistic efforts.
Students gain confidence in their individual mathematical abilities, by working cooperatively.
Peers heavily influence choices of which mathematics courses to take and what careers to consider.

The Accreditation Board of Engineering and Technology (Engineering Accreditation Commission, 1998) standards require that "Engineering programs must demonstrate that their graduates have... an ability to function on multi-disciplinary teams." As a result, team concepts and skills are now taught and practiced throughout engineering course curricula in the United States (Mead et al., 1999). Due to the increasingly global nature of engineering, opportunities for students to navigate the issues of distance, time, culture, language, and multiple perspectives associated with virtual teams are becoming particularly desirable. In addition to this, industry often requires engineers to work in teams; therefore many university engineering courses ask students to work in groups to complete design projects.

Many university engineering courses require students to work in small groups to complete a class project. This experience is often valuable for students going into an industrial setting where group projects are the norm (Russell, 2003). Learning to function in a group environment can be challenging itself, but the addition of technology as a medium of communication can often create as many obstacles as solutions.

At a state university in the USA, an Industrial/Manufacturing Engineering class implemented a group project using two methods of group communication -- face-to-face (F2F) and computer-mediated communication (CMC). Students were randomly assigned to complete a semester-long project in either a F2F or CMC group (Russell, 2003). Those in the F2F groups were instructed to meet in person to complete the project. Participants in CMC groups were instructed to communicate with each other only through electronic means, such as e-mail, electronic bulletin board, or virtual chat.

Aside from the comparison of performance of the F2F versus CMC groups on their class assignment, this study also examined participants' overall satisfaction with their
group process. Research in this area shows that groups communicating exclusively through technological means generally experience lower levels of member satisfaction than traditional F2F groups (Walther, 1996).

Scott's (1999) review of recent research on a wide range of technology-related communication issues presents studies that support this notion, but also includes results from studies showing CMC groups reporting equal or greater levels of member satisfaction than F2F groups. A closer look at Scott's (1999) review reveals that "member satisfaction" is defined in multiple ways. Some studies focus on member satisfaction with group "outcomes," while others reported satisfaction differences with regard to "group process." The latter can be further broken down into satisfaction with the "precision of the process" and the "accuracy of the process" (see Valacich et al., 1993).

A study conducted by Whitman et al., (2005) researched what were the effects of computer-mediated communication on project performance, selected group processes and student satisfaction during students' experience with virtual teams. The method chosen was to require students to work on a team project. Students in a graduate course on the principles of lean manufacturing were randomly assigned to one of two team conditions: face-to-face (F2F) or computer-mediated communication (CMC). There was no statistically significant difference in the final project scores between the students in the F2F and those in the CMC groups, but the variance of the CMC project scores was significantly greater than the F2F project scores.

In order to ensure that one group was not markedly different in terms of academic level, the individual GPAs of the students in each condition were compared, which revealed no significant differences. The greater variability in the project scores for the CMC groups may be an indication that lower performing groups were more affected by the computer-mediated communication than the higher performing CMC groups. Interestingly, the CMC groups felt more of a need to begin the project earlier as evidenced by the fact that the CMC participants reported earlier in the semester than their F2F counterparts that their groups had met at least 12 times or more.
At the end of the semester, Whitman et al., (2005) gathered subjective comments from participants on the final project experience through the final on-line survey. Not surprisingly, the sources of satisfaction for the F2F groups were focused on the learning that occurred in a collaborative project, while the CMC focused more on individual skill development. Both the F2F and CMC groups reported ineffective team members as sources of dissatisfaction, but the CMC groups commented that communications technology was also a source of dissatisfaction.

Whitman et al., (2005) did a comparison of student project performance which showed that both the F2F and CMC final project scores were comparable; however, there was significantly more variability of scores in the CMC condition. Patterns in group processes indicate that most of the students in the CMC groups were new to the use of technology as an exclusive means of communication and found the experience to be challenging. While the quality of the groups' projects was similar, the perceptions of effectiveness, satisfaction, and peer performance were significantly higher for the F2F groups.

Whitman et al., (2005) found that in terms of overall satisfaction, F2F group members were, in general, more satisfied with the team experience than the CMC team members, however, both groups were able to complete the project successfully and reported an overall positive experience. Many CMC team members noted that this experience enhanced their communication skills, increased their awareness of technological challenges facing computer-mediated teams, and provided valuable experience for future job opportunities in industry. As corporations become more global, the use of computer-mediated technology will continue to supplement and may even replace traditional F2F project teams.

Future research involving CMC should continue to examine both performance and social aspects of small group communication. As the tools become more pervasive, the learning curve for CMC groups should also decrease.
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3.5.5 Efficiency of collaborative learning - variables of interest

One factor that determines the efficiency of collaborative learning is the composition of the group, be it in either face-to-face or computer-supported environments (Dillenbourg & Schneider, 1995). Group composition is defined by several variables such as difference between group members based on age, gender, language background, and relocating to a different environment such as a new country to name a few. The most intensively studied variable is the heterogeneity of the group (Dillenbourg & Schneider, 1995). It refers to the objective or the subjective differences (how subjects perceive each other) among group members. These differences can be general (age, gender, intelligence, development, language or cultural background) or specific.

Past research has studied the effects of differences between gender, age and language background in a variety of contexts and therefore I made the decision to investigate the effects of age, gender, language spoken at home and the length of stay in Australia on students' views about collaborative learning and learning with CAS and subsequently used them as my variables for the study. In the following sub-sections, I discuss the effects of gender, language and cultural background of students. Not much has been investigated in the area of migrant status which relates to the number of years students have been in Australia.

• Language and cultural background of students

The use of group work in higher education is linked to teamwork skills as graduate attributes and outcomes in Australia, the USA, and the UK (Melles, 2004). On the one hand, institutional legitimation of group work is a response to industry demands for more relevant skills for students (Ackennann & Plummer, 1994; Bourner, Hughes, & Boumer, 2001), the increasing vocational nature of higher education, greater student accountability, and pedagogies of active learning (Kremer & McGuinness, 1998, p. 44).

Group work under various guises is also associated with a number of progressive theories or approaches to learning including constructivism (Hodder, 1998; see also Vygotsky 1962; 1978), student-centred learning (Lejk & Wyvill, 2001), experiential learning (McGraw & Tidwell, 2001) and collaborative and cooperative learning
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(Ackermann & Plummer, 1994; Mahenthiran & Rouse, 2000; Nance & Mackey-Kallis, 1997), which all aim to produce "greater involvement and accountability of students within the group" (Stoll, 1996, p260), redistribute power (Berge, 1998; Mahenthiran & Rouse, 2000), and promote student autonomy (Bourner et al., 2001, p20).

Although a number of different learning theories and labels are applied to group work such labels conceal a range of definitions and practices (Mutch, 1998, p51). Rather than limiting himself to such prescriptive labels, such as collaborative learning, Melles (2004) allowed students to generate, where they saw fit, definitions for the group work they were engaged in. Students were recruited where they saw themselves engaged in group work in different faculties and programs. A number of students referred to learning theories such as problem-based learning and collaborative learning, or teaching methods in general as underpinning or related to group work, but there accounts were as eclectic as those who did not (Melles, 2004).

Overall, despite the fact that meta-analysis of cooperative learning in groups is generally linked to improved thinking and problem-solving (Lee et al., 1997), whether group work practices improve learning experiences and outcomes remains "a matter for conjecture" (Kremer & McGuinness, 1998, p48). Feedback from students sometimes confirm their experience of these benefits and a "large and mainly optimistic body of research exists on the benefits of group work among peers" (Leki, 2001, p40).

As MacCallum (1994) notes, perceptions among students within a class of the goals, aims, and processes of collaborative learning vary substantially. Leki (2001) in a qualitative analysis of non-native students in the USA found that in general difficulties facing non-native English speakers were invisible in course evaluations such as questionnaires, "often the disappointing features of the group work appeared to be invisible to the course instructor, sometimes hidden behind positive evaluations of the final group project itself" (Lejk & Wyvill, 2001).

To remedy the existing limitations of survey studies, Volet (1999) suggests that to understand learning practices across cultures we need to look at staff and student perceptions of learning in the home and host country arguing that only through such in-
depth qualitative approach can stereotypical constructions of the foreign student as "other" be remedied (Melles, 2004).

In Australasia, cultural difference is used to explain different approaches to group work and learning by non-Western students (for example Andrews & Dekkers, 1999; Anyanwu, 2000; Baker & Panko, 1998), and cultural difference is often positioned as a problem. McGraw and Tidwell (2001), for example, refer to culturally different approaches to work among problems with group work. Claims about the lack of participation by Asians in group work sometimes focus on language difficulties but also stress the lack of independence or autonomy and dependence on uncritical acceptance of authority figures as part of their cultural baggage (Baker & Panko, 1998; Chapple, 1998). The sometimes unstated assumption in this claim is that Asian students lack of participation is a cultural disposition although this contradicts the collectivist ideology identified for confucianist cultural explanations (Chan, 1999; Redding, 1990).

As Kubota (2001) has argued, the tendency to "essentialise the culture of ESL/EFL students . . . as categorically different from the perceived culture of students in English-speaking cultures" (p10), a discursive construction of "other" (Pennycook, 1998); serves as a form of gate keeping to educational and social change. While cultural difference may have some explanatory power, it is insufficient on its own to explain the similarities students perceive, and the literature supports in the learning approaches of native and non-native speakers (Melles, 2004).

Survey-based studies also question this construction of the learner as different. Littlewood (2000) concludes that there is less difference in attitudes to learning between Asian and European countries than between individuals within each country. Ramburuth and McCormick (2001) discovered that there were no statistically significant differences between Asian and Australian students in their approaches to learning, although they did differ in their learning strategies and styles with Asian learners preferring more collaborative and group learning.
• Gender differences

Recent research on gender in many countries has focussed on boys’ underachievement and disaffection (Weaver-Hightower, 2003). In mathematics, however, gender differences favouring males persist. Males participate more than females in higher-level mathematics (Fullarton & Ainley, 2000). The Third International Mathematics and Science Study (TIMSS) found that at the end of secondary school males in most countries achieve better than females in mathematical literacy, and among students still studying mathematics in Grade 12, males' attitudes are more positive than females' (Mullis et al., 2000). This indicates a continuing need to focus on the role of gender in mathematics learning, and especially to encourage girls to participate in higher-level courses, monitor their experiences, and ensure that instructional practices meet their needs.

Collaborative approaches have been widely recommended as strategies to encourage girls' participation and achievement in mathematics. Among reasons given are that most girls prefer collaboration to competition (Cordeau, 1995; Owens, 1985); girls tend to achieve better in collaborative environments (Peterson & Fennema, 1985; Seegers & Boekaerts, 1996); and collaboration supports and encourages risk-taking, facilitates 'connected' learning, and produces a less hierarchical classroom (Jacobs, 1994; Morrow & Morrow, 1996; Solar, 1995). Studies of girls-only groupings have shown that girls generally communicate well and enjoy and benefit from collaboration (Bruner, 1996; Morrow, 1996).

Research into collaborative learning enthusiastically supports collaboration as having a "favorable impact on children's learning motivation and attitudes in school" (Joiner, 1996). Computer-supported collaborative learning enjoys the same support. The use of computers for interactive collaboration facilitates new representations of knowledge (Joiner, 1996). Many educators and parents fear that the use of computers may decrease social skills in children; however, studies have shown that often students work together to solve problems and seek advice from each other. Use of computers may tend to increase social skills. "The interchange between the most intellectually interesting students" that computer-supported collaborative learning provides is a valuable resource in the classroom (Joiner, 1996).
As noted by Belenky et al. (1986) girls tend to favour connectedness and relationships in education. Collaborative learners value others and understand that learning is social. They also typically value diversity and multiple perspectives. Girls generally favour this type of learning. In a study of students involved in computer-supported collaborative learning, "the greater chance for social interaction" was named as a best outcome, showing student value of CSCL (Rowe, 1993). Software should support the collaborative effort to truly engage girls, otherwise they may simply become observers and not participants. "Collaborative learning is a well-documented successful pedagogical strategy. Somewhat serendipitously computer-based learning naturally increases collaboration within the classroom environment" (Joiner, 1996). Computer-supported (and face-to-face) collaborative learning can be made to be more appealing to the natural learning style of girls if the previously mentioned barriers can be overcome. Thus, girls have the opportunity for thriving in this environment.

According to Barnes (2003), relatively little research has studied, from a gender perspective, the social interactions during collaborative mathematics learning in coeducational settings. Forgasz (1995) observed students in mixed-sex groups, finding that they adopted gender-stereotyped roles and failed to collaborate effectively. She suggested that this helps to explain gender variations in attributional beliefs. Stevens (2000), describing interactions among four students in a project-based classroom, revealed within-group tensions, based partly on gender and partly on perceived ability. Students were positioned differently depending on how they perceived the task.

Vale (2001) found gender differences in computer-based secondary mathematics. Boys were more likely to compete, take control of their learning, regard computers as a male domain, share computer knowledge, and be perceived as experts. Girls were successful peer tutors, and more likely to be concerned about whether computers aided their mathematics learning. Vale (2001) also found important within-gender differences: high-achieving boys displayed dominant behaviour; low-achieving boys strove to identify with computer experts; high-achieving girls persisted as "experts within"; other girls backed off. A few exceptional girls challenged gender stereotypes. None of these studies, however, focussed on advanced mathematics, where gender differences in achievement and participation remain of greatest concern.
Armstrong and Leder (1995) found that despite recent efforts to increase the numbers of females in engineering courses, the proportion has plateaued at an average of less than 20%. To increase the proportion further many believe that the way engineering courses are structured and presented must be changed. Demand for change in engineering education is also coming from a number of other directions as has been demonstrated in recent surveys of engineering graduates and engineering employers.

Despite the lack of research on the interaction of gender and the nature of engineering courses, there has been much research in closely related fields such as secondary school science and mathematics. In general, this work has shown that girls are more interested in science if the total context rather than isolated technical tasks are emphasised. Engineering courses should be changed so that they better meet the expectations of employers and graduates. This can be done in a way which also makes them better suited to female students (Armstrong & Leder, 1995). Content of courses should be pruned to eliminate the overload. Engineering topics should be treated in a total context which includes social, environmental and political considerations as well as technical aspects.

3.5.6 Using computers in a collaborative learning environment

Crook (1994) has widely analysed how computers can facilitate collaborative learning in schools. He makes a distinction between interacting around and through computers. The first perspective stresses the use of computers as tools to facilitate face-to-face communication between student pairs or in a small group. According to Crook (1994, pp. 189-193), technology in these situations may "be serving to support collaboration by providing students with something he calls points of shared reference". He claims that a traditional classroom situation is too thinly resourced for successful collaboration. There are not enough available anchor points at which action and attention can be coordinated.

- Effects on learning and achievement

There is a substantial research which shows that cooperative and collaborative conditions are helpful for learning (Slavin, 1991). This especially applies in conditions where the division of labour and collective incentives emphasise high achievement by
all group members. Most of the effectiveness evidence of collaborative learning comes from short-term experiments and is based on rather mechanistic cognitive achievement. Theories of collaborative learning are based on the notion that knowledge construction is basically a social event, and adequate collaboration is particularly important for learning complex knowledge and higher order cognitive skills. One of the success stories of collaborative learning is the so-called reciprocal teaching developed by Palincsar and Brown (1984). This model has also proved to be successful in many later experiments using similar conditions (Järvelä, 1996). However, what is the added value of computers in collaborative learning environments?

Various meta-analyses on the effectiveness of computers have shown that in the majority of experiments the use of technology has markedly improved the learning outcomes (Fletcher-Flinn & Gravatt, 1995; Khalili & Shashaani, 1994; Kulik, 1994). These studies do not, however, distinguish between different pedagogical ideas on how computers have been implemented in classrooms. Thus, it is impossible to draw any conclusions about the effectiveness of CSCL on the basis of these general impact studies.

Empirical experiments such as Scardamalia et al., (1994) offer some evidence that the well-known CSCL environments like Computer Supported Intentional Learning Environments (CSILE) and Belvedere have proved to be helpful for higher order social interaction and, subsequently, for better learning in terms of deep understanding. What is still lacking is the evidence that the same results could be achieved widely in normal, traditional classrooms. It is also possible that similar positive results could be reached in classrooms carrying out the same collaborative activities without computers.

Although hundreds of papers on CSCL have been published during the last few years there have not been very many well-controlled experiments that could answer the questions concerning the wider applicability of CSCL in normal classrooms, and whether there is the added value of computers and networks in comparison to collaborative learning environments without technology.
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There are numerous studies on CSCL environments demonstrating encouraging effects on the amount and quality of social interaction and other procedural features of teaching-learning processes (Amigues, & Agostinelli, 1992; Crook, 1994; Davis & Huttenlocher, 1995; Fishman & Gomez, 1997; Lamon et al., 1996; McConnell, 1994; Rysavy & Sales, 1991; Scardamalia et al., 1994; Suzuki & Hiroshi, 1997). Besides these optimistic papers there are also a couple of research reports that try to analyse the shortages and problems students have when participating in CSCL learning environments.

In particular, general passivity and uneven distribution of participation are common but seldom thoroughly analysed problems in collaborative learning environments (Eraut, 1995; Lehtinen et al. 1997). When it concerns communication through computers, the constraints of social interaction are different from the face-to-face communication (Lea, 1992; Walther et al., 1994). These changes in communication have not been sufficiently analysed in recent research on the interaction processes in computer-supported collaborative learning and nor the consequences for learning.

Sfard (1998) has made a division into two main metaphors of learning: the acquisition metaphor and the participation metaphor. Questions concerning learning outcomes belong to the more traditional acquisition paradigm, which interprets learning in terms of the acquisition of something in an individual mind and knowledge in terms of property and possession. The ideas of collaborative learning at least partly belong to the emerging participation metaphor. According to this approach, it is not meaningful to ask how much or how organised is the knowledge an individual student has acquired. Instead, this approach deals with learning as becoming a participant and with knowledge as an aspect of practice, discourse and activity.

I agree with Sfard (1998) that both of the two metaphors of learning (acquisition and participation) are needed. The acquisition approach should not be fully replaced by the emerging participation approach. This means that, besides the description of activities and discourse processes, we should also consider the knowledge acquisition of individual students in CSCL environments. However, it is important to recognise that the attempt to infer direct causal relations between the use of a certain computer
application and learning outcomes can be misleading. Salomon (1994; 1996) has strongly stressed this problem. He has suggested a more systemic approach, where the patterns of change should be analysed rather than simple causal effects between independent and dependent variables.

3.6 What is happening in undergraduate mathematics learning and teaching in Australasia?

An analysis carried out by Wood (2003) examined research on learning and teaching in universities in Australasia and looked at major themes such as bridging and adult education; the first-year experience; higher-level mathematics; graduate attributes; student perceptions and motivation; gender; technology; assessment; cross-disciplinary teaching and learning; and studying the teachers.

I will outline what is happening in undergraduate mathematics learning and teaching in Australasia in relation to the first-year experience, gender, technology and assessment as these are attributes of interest in my investigation, acknowledging the work of Wood (2003). This section is not intended to describe issues that make the Australian setting difference from other countries. Also, to keep it in context with the current investigation, an emphasis on research conducted by Australasian authors was made.

3.6.1 Research relating to the first-year experience

Within tertiary institutions, many students study mathematics only at first-year level, so the level of interest in first year is substantial. In Australia, from 1990-2000, the total number of students in higher education increased by 43% to just under 700,000, while the number of overseas students increased by a factor of 4 to just under 100,000 (Department of Education, Science and Training, 2002; in Wood, 2003). With this increase in number and cultural diversity comes an increase in academic diversity.

In a discussion of first-year mathematics and statistics curriculum, Varsavsky (2001) questions the relevance of current content. She is motivated by the need to place generic skills more centrally within the curriculum. She believes that a ‘fundamental
reinterpretation of the roles of lecturers, tutors and learners in the learning process is needed to prepare students for "life after exams" , (p 146).

Barnard (2003) has similar conclusions in her report on a study of learning styles of students at the beginning and end of first year. She states that 'if the aim of university education is to modify students' learning patterns and promote autonomous learners' (p. 7) then the current course structure does not fulfil this aim. Pierce et al., (2003) have had a positive student response to revised curriculum which uses thematic contexts, realistic problems and a range of student-directed and group tasks.

Henderson and Britton (2003) investigated students' ideas about the qualities of a perfect tutorial. Students did not agree on a single model and wanted more accessible tutors, smaller class sizes and more drill questions. The issues raised probably reflect the difficulty of transition to a tertiary environment. Taylor and Mander (2003) argue for the explicit teaching of time management and study skills in first-year to assist with the transition to university mathematics.

In discussing specific mathematical content areas, Stewart and Thomas (2003) investigated students' difficulties with linear algebra and found that students had difficulty with definitions, used a procedural rather than conceptual approach and an inability to translate between representations, particularly a geometric perspective. They suggest that developing geometric perceptsives would help with conceptual understanding.

Collaborative learning and peer tutoring methods are rarely used in university mathematics. D'Souza and Wood (2003d, 2003e) report on a study of introducing collaborative learning and assessment in a large first-year engineering mathematics subject. They provide a rationale, based on general education literature, for using collaborative learning (D'Souza & Wood, 2003d) and present an analysis of students' views about group work in mathematics (D'Souza & Wood, 2003e). These findings connect existing literature with the context of tertiary mathematics teaching and learning and show that the benefits reported in the literature in a variety of contexts are applicable to tertiary students mathematics.
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Peer tutoring for first-year undergraduate students is described in Evans et al., (2001). Though this study was undertaken in the UK, results for Otago (New Zealand) are also discussed. Qualitative evaluation showed positive results - student enjoyment was high and there appeared to be no disadvantage to having been taught by peers instead of tutors. As with many innovations, assessment was the most difficult issue and the authors argue for the use of self-assessment.

3.6.2 Research relating to gender

This variable is one that is often studied when considering teaching and learning mathematics (Wood, 2003). Due to the lower representation of women in all levels of mathematics at the tertiary level, there is interest in studying gender effects of teaching interventions. It is important however, that proposed reforms to teaching and learning do not adversely affect any particular group.

Research carried out by Galbraith and Haines (2000) used six scales - mathematics confidence, mathematics engagement, computer motivation, computer confidence, computer-mathematics interaction, and mathematics motivation to explore students' attitudes. When analysed by gender, scores on mathematics confidence were comparable. However, for mathematics engagement and mathematics motivation, females exhibited more positive attitudes than males, perhaps reflecting their choice to enter male-dominated degree programs. For the computer-related scales, males scored significantly more positively than females. Wood et al., (2003) found that inclusive classroom practices and collaborative assessment tasks positively influence the outcomes for female students. Given the changes in using technology in university mathematics teaching and learning and in working as a mathematician, this is clearly an area for further investigation.

An investigation by Cretchley et al., (2000) of factors that influence students' choice of field of study, explored differences between 541 students from two city and two regional universities in Queensland, Australia. Analysis of differences in students' reasons for their choice by gender and regional area noted that interest in the subject followed by strength in subject and employment prospects were the strongest influences.
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Gender and regional differences were not significant. The teacher was an important influence on choice of mathematics, particularly in regional areas.

3.6.3 Research relating to technology

Advances in information and communication technology (ICT) have radically changed the teaching and learning of mathematics at many universities. Students' attitudes towards technology and learning in mathematics are the subject of several studies (see for example Cretchley & Galbraith, 2003; Galbraith and Haines, 2000; Saunders, 2003). Fogarty et al., (2001) report on the validation of Galbraith & Haines (2000) questionnaire designed to measure general mathematics confidence, general computer confidence, and attitudes towards the use of technology for mathematics learning. They found that the scales - on the basis of factor analysis - demonstrated high internal consistency reliability and divergent validity.

Other studies, such as Cretchley and Galbraith (2002), Cretchley and Harman (2001), have also investigated students' confidence and motivation using the scales developed by Galbraith and Haines (2000). These studies considered the affective domain including confidence, attitudes, motivation and engagement. They found that mathematics attitudes (both confidence and motivation) correlated strongly with achievement in mathematics and that attitudes about using technology in mathematics learning correlated far more strongly with computer attitudes than with mathematics attitudes.

Cretchley et al., (2000) describe an investigation into the effects on attitudes and learning of introducing scientific software into a large and diverse first year university mathematics class. The study confirms the affective potential of this kind of technology. This is important work and contrasts with the work of others who are busily introducing technology into mathematics teaching and learning at university without consideration of the consequences for groups of students. There should be more informed debate about technology and its use.

Coupland (2000) reports that students' opinions of the use of Mathematica in their first-year subject produced positive, neutral, negative responses in the ratio 25:27:47. Gender
or language background were not significant variables in whether a student had a positive experience using the computer algebra system. Previous computing experience seems to help, which echoes the findings of others (Galbraith et al., 2001).

A large body of work considers the use of computer algebra packages in first year courses (Colgan, 2000; Blyth, 2001; Blyth, 2003; Blyth & Nairn, 2001; Pemberton, 2002a). These studies are of interest to mathematics lecturers and deal mainly with practice. The authors are all evangelists for using computer algebra systems in mathematics teaching and learning. However, the presence of computer algebra systems in the curriculum does not automatically mean that learning is taking place.

As reported by Coupland (2000) and Henderson (2002), many students find the use of computer algebra systems unrewarding. Pierce and Stacey (2002) present a useful framework to determine how effectively students use a computer algebra system both to do and to learn mathematics. Many university mathematicians would find the framework useful in designing their teaching, learning and assessment strategies. Saunders and Blyth (2001) also consider how to use technology to optimise student learning.

Several articles question the position of technology in university mathematics teaching and learning. Cretchley (2001) looked at data gathered from 34 undergraduate mathematics students and found that the majority were positive about the use of computing but also were positive about the use of hand exercises in the early stages of concept development. Galbraith et al., (2001) and Galbraith and Pemberton (2002) investigated the relationships between computers, mathematics and learning. Wood and D'Souza (2003) question the use of computer algebra systems and conjecture that we are making too many demands on beginning students, requiring them to learn mathematics and computer algebra systems.

3.6.4 Research relating to assessment

Research carried out by Wood et al., (2002) discussed the link between students' performance in a linear algebra examination and categories of the MATH taxonomy (see Smith et al., 1996 for explanation of the MATH taxonomy). In general, there was a
high level of correlation on performance between different types of task and no interaction with the language background of students. A few students demonstrated that they could perform well on conceptual tasks without performing well on techniques. This is an interesting area for further research.

Wood and Smith (2002) examined students' perceptions of difficulty of tasks. Contrary to expectations, there was not a strong link between familiarity (prior experience of the type of task) and students' perception of difficulty. Students were sufficiently familiar with some types of task to perceive their difficulty. Language factors were not important, neither the language of the question nor the language background of the students except for one question that clearly required language skill.

Different conclusions were found by Barton and Neville-Barton (2003) who investigated the influence of language-background on students' understanding of mathematical questions in examinations. They found that students whose first language was not English suffered approximately a 10% disadvantage in examination scores. Smith & Wood (2000) discuss the ways in which assessment can be used to enhance student learning, the impact of external factors on assessment methods and barriers that inhibit change.

Hubbard (2001) develops the controversial argument that conventional examinations should be removed. From her experience and a review of literature, she concludes that the most effective way to promote higher-level approaches to learning is to devise assessment schemes -which reward higher-level learning rather than memorisation of procedures. Alternate assessments advocated were project-based assignments individually or in groups and that the tasks in assignments be designed to develop conceptual understandings.

### 3.7 Synopsis of chapter

This chapter has reviewed literature pertaining to different learning style preferences; to computer technology applications in general, and computer algebra systems in particular; and to the use of collaborative learning methods in either face-to-face or
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computer-supported environments. The chapter also looked at research in undergraduate mathematics education in Australasia in particular, and reviewed literature relating to the first-year experience, gender, technology and assessment.

As computers become accessible to all students, changes can be made in the classrooms that enrich students' experiences in mathematics. Even though the use of computer technology has potential for assisting students to learn mathematics and teachers are being encouraged to use this technology, not all have taken up this challenge. Some of the reasons for this are a lack of instructors' knowledge of the technology and its potential use for the learning of mathematics; suitable instructional materials to allow them to incorporate the technology into their teaching, time to undertake explorations into these areas and facilities available.

A large body of work in the field deals with specific mathematical content. Many of these articles contain little reflection, little evaluation or awareness of previous work in the area. Whilst the work may be of interest at present, the long-term importance of the publications to mathematics education research is questionable.

Other work examines innovations in teaching method and the uses of technology - especially graphics calculators and computer algebra systems – in mathematics teaching and learning. Again, some of the articles are directed to specific content and contexts and contain little evaluation. It can be difficult to generalise from these to other contexts, and the situations may lose relevance as technology changes. Other studies build on the work of previous investigators and generalisations can be made. Changes in teaching methods due to computer algebra systems will be a continuing research area as it is still not clear how mathematics should be taught incorporating these systems. There is considerable angst in the mathematics community about how much mathematics should be done by hand and how much by machine. This debate is largely resolved in statistics, with most courses using statistical software.

In relation to the literature on collaborative learning, there is an overall positive effect in the cognitive domain as well as the social and affective domain in education at secondary and tertiary levels in general. However, there is still scope for further
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research into collaborative learning in undergraduate mathematics classrooms. There is no doubt that implementing collaborative learning is a structured but complex process.

There have been numerous studies on the transition from secondary school to university mathematics study and bridging courses for students starting university including bridging courses for specific groups of students, such as nurses and engineers, are well investigated. There has been some work on diagnostic testing to advise students into the appropriate bridging programs. This is particularly important for distance education and for first-year students who may need additional support.

Other research looks at the way students understand particular areas in mathematics, and seeks to classify their conceptual development and track changes, for instance, students' understanding of matrix algebra or differential equations. Innovative approaches to assessment have been used to obtain information on student learning and to encourage students to engage with a wider variety of mathematical ideas. A common thread in these studies is the investigation of students' ideas of a particular topic as an indication of their mathematical development. The artefacts of student learning, such as assessment tasks or exams, supported by observations of behaviour, are used to discover the range of students' notions about the topic.

Changes in teaching and learning styles are not a quick and easy matter. Change is a gradual process that involves both trying out new strategies and techniques as well as carefully considering the goals for which those practices are intended. With patience, persistence and the right kind of support, instructors can hopefully make constructive changes in instructional practice. Instructors are currently faced with a variety of challenges like large class size, diverse student populations, management problems, accountability pressures, legal issues, curriculum changes and new technology. The use of collaborative-learning strategies can make classroom life for teachers and students more supportive, engaging, intellectually stimulating, creative, mathematically productive and fun.

Looking at research trends in mathematics education and the current state of mathematics education research in Australia, reveals a research community committed
CHAPTER THREE: REVIEW OF LITERATURE

to the production of knowledge relevant to mathematics education. From it, we learn that different methods and approaches sit comfortably alongside each other. Many models of research are being validated, and with those models there are many methodologically rigorous ways of engaging with the data for developing an understanding of the complexity of teaching and learning.

Research undertaken at the primary, secondary and tertiary level does not really figure equally, but in most contexts, it is the student who receives most research attention. An interest in number spills over into studies of how students learn and how teachers might develop ways to teach. The time devoted to exploring where we are and where we wish to go is a wise investment. Tertiary mathematics educators, need to take the lead in attempting to resolve the major educational questions within our sector and answers should be informed by a strong research base, both past and present, alongside a vision for the future.

Australasian research has made quite significant impact during the last two decades in the areas of (i) gender and mathematics, (ii) language and mathematics, (iii) socio-cultural aspects of mathematics teaching and learning, (iv) early childhood mathematics, (v) teacher education and the teaching of mathematics, and (vi) cognitive aspects of mathematical learning.

What can we learn from this research profile? We can learn about what students are learning, how best students learn, and how teachers are organising their teaching. We can draw on this research knowledge and the insights it offers to enlighten the debate about things that are most important in mathematics education. We can go one step further by using the insights to shape the nature of curricular and pedagogical decisions.

Doing this promises exciting potential for further development of leading edge knowledge about mathematics teaching and learning in Australia. We have to be aware that this requires a high level of collaboration between researchers, teachers, and policy makers. Teams of researchers and teachers with different perspectives need to work together developing new research questions, enhancing existing methodologies, and complementing their analyses of data.
Chapter 4

Methodology and design

4.1 Introduction

This chapter discusses the methodology that has been adopted in this project. The design of the study is described as well as the participants in this project, the materials used and the methods of data collection.

After having framed the problem or field of interest, the next step for most research is often the method to be used. The term 'methodology' is used to encompass the whole design of this study, and should be viewed as distinct from the description of the actual methods employed.

Bishop (1992) states that often in the past, the method itself has actually led the research, and he argues strongly instead for problem-led research when he states that the intention should be to, "use whatever research procedures seem appropriate and useful for shedding light on the problem" (p716). He attributes the past lack of problem-oriented research to the fact that, "truly problem-led approach has tended not to be possible in our field because of the limited range of research procedures assumed to be legitimate" (Bishop, 1992, p716). The argument about legitimacy is central to the historical debate between quantitative and qualitative methods (Oates, 1998).
4.2 Selecting appropriate methods - quantitative, qualitative or both?

Interestingly the decision to use a balance of quantitative and qualitative methods in this study can be clearly viewed as supporting Bishop's (1992) place regarding the influence of tradition on methodology. The researcher's qualifications in mathematics and statistics have built a predisposition towards quantifiable studies and techniques but, as will be seen, combinations of both quantitative and qualitative methods have been employed.

Quantitative research surveys do not necessarily provide all of the data needed to develop effective communications. Consequently, qualitative methods such as focus groups and in-depth interviews, as well as less precise but useful semi-quantitative approaches, such as intercept surveys, have emerged as part of the research repertoire of researchers. In education, researchers use both quantitative and qualitative data to provide a more complete picture of the issue being addressed, the target audience and the effectiveness of the program itself.

4.2.1 Qualitative and quantitative methods: A comparison

An examination of the quantitative and qualitative paradigms will help to identify their strengths and weaknesses and how their divergent approaches can complement each other. In most cases, researchers fall into one of the two camps – either relying exclusively upon 'objective' survey questionnaires and statistical analyses and avoiding warm and fuzzy qualitative methods, or using only qualitative methodologies, rejecting the quantitative approach as decontextualising human behavior (Weinreich, 1996). However, social marketing researchers recognise that each approach has positive attributes, and that combining different methods can result in gaining the best of both research worlds.

Quantitative research uses methods adopted from the physical sciences that are designed to ensure objectivity, generalisability and reliability. Techniques cover the ways research participants are selected randomly from the study population in an unbiased
manner, the standardised questionnaire or intervention they receive and the statistical methods used to test predetermined hypotheses regarding the relationships between specific variables. The researcher is considered external to the actual research, and results are expected to be replicable no matter who conducts the research (Weinreich, 1996).

The strengths of the quantitative paradigm are that its methods produce quantifiable, reliable data that are usually generalisable to some larger population. Quantitative measures are often most appropriate for conducting needs assessments or for evaluations comparing outcomes with baseline data (Weinreich, 1996). This paradigm breaks down when the phenomenon under study is difficult to measure or quantify. The greatest weakness of the quantitative approach is that it decontextualises human behavior in a way that removes the event from its real world setting and ignores the effects of variables that have not been included in the model.

Qualitative research methodologies are designed to provide the researcher with the perspective of target audience members through immersion in a culture or situation and direct interaction with the people under study. Qualitative methods used in social marketing include observations, in-depth interviews and focus groups. These methods are designed to help researchers understand the meanings people assign to social phenomena and to elucidate the mental processes underlying behaviors (Weinreich, 1996). Hypotheses are generated during data collection and analysis, and measurement tends to be subjective.

In the qualitative paradigm, the researcher becomes the instrument of data collection, and results may vary greatly depending upon who conducts the research. The advantage of using qualitative methods is that they generate rich, detailed data that leave the participants' perspectives intact and provide a context for health behavior. The focus upon processes and 'reasons why' differs from that of quantitative research, which addresses correlations between variables. A disadvantage is that data collection and analysis may be labour intensive and time-consuming.
4.2.2 Selecting methodology

I decided to use a combination of quantitative and qualitative methodologies. In choosing a suitable combination of quantitative and qualitative methods, Miles and Hubennan (1994) raise some questions which need to be addressed such as, "Are the quantitative and qualitative sides of equal status? Are they interactive or separate? How are they sequenced?" (p41). As well as an overall design for the research, the specific methods to be used also have to be selected. Romberg (1992) lists 13 different methods of investigation that may be used when a situation arises and evidence must be developed.

Janesick (1994) expands even further on the qualitative methods in this list, offering 18 different qualitative strategies from which to choose the most appropriate for a given study. When actually selecting methods from any available set, Miles and Hubennan (1994) advise against falling into a 'default mode', which sees a particular method as the only way of proceeding: "Think whether your study can actually benefit from a particular qualitative aspect or component. Think purposes and think ahead" (Miles & Huberman, 1994, p43). Janesick (1994) gives a list of what she terms design decisions which suggest some further criteria that should be considered when making this choice. These are shown below in Table 4.1.

<table>
<thead>
<tr>
<th>Table 4.1: Decisions in the design of research (from Janesick, 1994, pp. 211-212)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The questions that guide the study.</td>
</tr>
<tr>
<td>2. Selection of a site and participants.</td>
</tr>
<tr>
<td>3. Access and entry to the site and arrangements with the participants.</td>
</tr>
<tr>
<td>4. Timelines for the study.</td>
</tr>
<tr>
<td>5. Selection of appropriate research strategies.</td>
</tr>
<tr>
<td>6. The place of the theory in the study.</td>
</tr>
<tr>
<td>7. Identification of the researcher's own beliefs and ideology.</td>
</tr>
<tr>
<td>8. Identification of appropriate informed consent procedures and willingness to deal with ethical issues as they present themselves.</td>
</tr>
</tbody>
</table>

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CHAPTER FOUR: METHODOLOGY AND DESIGN

The principal factors upon which the final decision for specific methods was made (see lists in Janesick, 1994, p212, Miles & Hubemian, 1994; Romberg, 1992, p.56) are summarised in Table 4.2. The research questions suggested that a questionnaire should be administered and interviews conducted to draw out student's perceptions. The questions are listed below as a recap:

1. What are tertiary students' preferred learning styles?
2. What are students' opinions about group work in mathematics?
3. Does collaborative group work foster a deep, meaningful understanding of mathematics?
4. What are students' attitudes about using CAS such as Mathematica?
5. What are students' attitudes about the assessment of group-based work?
6. Are there any differences in students' learning style preferences across the various demographics?
7. Are there any differences in students' attitudes towards collaborative learning methods across the various demographics?
8. Are there any differences in students' attitudes towards the use of Mathematica across the various demographics?
9. Are there any variations in students' attitudes towards the assessment of group work in mathematics across the various demographics?

Influential factors in collaborative learning environments of interest to this study, identified in chapter I as well as in the review of literature, suggested the nature of some of the questions that should be included in the questionnaire. The researcher's intimate knowledge of and involvement in the teaching of the mathematics subject, Mathematical Modelling 1 at UTS, suggested an action research methodology be adopted. The definition of what is action research and what the process entails will be taken up in the next section. The resultant design of this research project includes three methods of data collection - questionnaires administered to students, interviews with students and assessment of students' coursework.
CHAPTER FOUR: METHODOLOGY AND DESIGN

Table 4.2: Factors considered when selecting the methods used in this study

1. Issues of interest identified in the literature.
2. The research questions.
3. Access to participants and participant's agreement.

The questionnaires were mainly quantitative in nature with some open-ended questions, and the items in the questionnaires were then used to inform the qualitative process of interviewing students. As Miles and Huberman (1994, p42) state in summarising the benefits of such mixed-method designs, "the careful measurement, generalisable samples, experimental control, and statistical tools of good quantitative studies are precious assets. When they are combined with the up-close, deep, credible understanding of complex real-world contexts that characterize good qualitative studies, we have a powerful mix". A fuller description of how each of the selected methods was used in the study is provided in the next section.

4.3 Methodology adopted for this project

"If you want it done right, you may as well do it yourself". This maxim may seem appropriate if one is a housekeeper, but more and more people are beginning to realise it can also apply to large corporations, community development projects, and even national governments. Such entities are of increasing importance in an interdependent world, and many are relying on action research as a means of coming to grips with their constantly changing environments. Research studies fall under two general types namely, basic and applied. The former addresses theoretical questions, while the latter seeks to answer practical questions, that is, it seeks results that can be applied directly. One special type of applied research is action research.

4.3.1 What is action research?

- It is a three-step spiral process of: planning which involves reconnaissance: taking actions; and fact-finding about the results of the action. (Lewin, 1947).
- It is a process by which practitioners' attempt to study their problems scientifically in order to guide, correct, and evaluate their decisions and actions (Corey, 1953).
• It is a systematic study or attempt to improve educational practice by groups of participants through their own practical actions and by means of their own reflection upon the effects of those actions (Ebbutt, 1985).

• It is a form or reflective inquiry undertaken by participants (e.g. teachers, students, principals) in social (including educational) situations in order to improve the rationality and justice of their own social or educational practices, their understanding of these practices, and the situations (and institutions) in which these practices are carried out (Carr & Kemmis, 1986).

• It is a process through which teachers collaborate in evaluating their practice jointly; raise awareness of their personal theory; articulate a shared conception of values; try out new strategies to render the values expressed in their practice more consistent with educational values they espouse; record their work in a form which is readily available to and understandable by other teachers; and thus develop a shared theory of teaching by researching practice. (Elliott, 1991)

Action research is known by many other names, including participatory research, collaborative inquiry, emancipatory research, action learning, and contextual action research, but all are variations on a theme. Put simply, action research is "learning by doing" - a group of people identifies a problem, does something to resolve it, sees how successful their efforts were, and, if not satisfied, tries again. While this is the essence of the approach, there are other key attributes of action research that differentiate it from common problem-solving activities that we all engage in every day.

A more succinct definition according to Cherry (1998) is: action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction. Accomplishing this twin goal requires the active collaboration of researcher and client, and thus it stresses the importance of co-learning as a primary aspect of the research process.
CHAPTER FOUR: METHODOLOGY AND DESIGN

What separates this type of research from general professional practices, consulting, or daily problem solving is the emphasis on scientific study, which is to say the researcher studies the problem systematically and ensures the intervention is informed by theoretical considerations. Much of the researcher's time is spent on refining the methodological tools to suit the exigencies of the situation, and on collecting, analyzing, and presenting data on an ongoing, cyclical basis. Several attributes separate action research from other types of research.

A primary difference is its focus on turning the people involved into researchers, too - most people learn best, and more willingly apply what they have learned, when they do it themselves. It also has a social dimension - the research takes place in real-world situations, and aims to solve real problems. Finally, the initiating researcher, unlike in other disciplines, makes no attempt to remain objective, but openly acknowledges their bias to the other participants.

4.3.2 The action research process

Kemmis developed a simple model of the cyclical nature of the typical action research process (Figure 4.1). Each cycle has four steps: plan, act, observe, and reflect. Susman (1983; cited in O'Brien, 2001) gives a somewhat more elaborate listing and distinguishes five phases to be conducted within each research cycle (Figure 4.2).

Initially, a problem is identified and data is collected for a more detailed diagnosis. This is followed by a collective postulation of several possible solutions, from which a single plan of action emerges and is implemented. Data on the results of the intervention are collected and analysed, and the findings are interpreted in light of how successful the action has been. At this point, the problem is re-assessed and the process begins another cycle. This process continues until the problem is resolved.
CHAPTER FOUR: METHODOLOGY AND DESIGN

Figure 4.1: Action research cycle (from MacIsaac, 1995)

Figure 4.2: An elaborate listing of the action research process (adapted from Susman, 1983)
4.3.3 Action research design

To refresh, the essentials of action research design are as per the following characteristic cycle:

- Initially an exploratory stance is adopted, where an understanding of a problem is developed and plans are made for some form of interventionary strategy. *(The Reconnaissance & General Plan)*
- Then the intervention is carried out. *(The Action in action research)*
- During and around the time of the intervention, pertinent observations are collected in various forms. *(Monitoring the implementation by Observation)*
- The new interventional strategies are carried out, and the cyclic process repeats, continuing until a sufficient understanding of (or implementable solution for) the problem is achieved *(Reflection and Revision)*.

The protocol is iterative or cyclical in nature and is intended to foster deeper understanding of a given situation, starting with conceptualizing and particularizing the problem and moving through several interventions and evaluations. A representation of an action research protocol by Kemmis & McTaggart (1990b) is provided in Figure 4.1 above.

The figure clearly displays the iterative nature of action research along with the major steps of planning, action, observation and reflection before revising the plan. This may be thought of as similar in nature to the numerical computing technique known as successive approximation - the idea is to close in upon a final goal or outcome by repeated iterations. Later protocols reflect changes in the goal as determined via experience during the reflections of earlier iterations of action research. For instance, Figure 4.3 reflects the evolution of the general idea or main topic of interest throughout the process.
CHAPTER FOUR: METHODOLOGY AND DESIGN

The model in Figure 4.3 emphasises constant evolution and redefinition of the original goal through a series of reconnaissance recurring every cycle. The reconnaissance necessarily includes some degree of analysis. This design permits much greater flexibility, and seeks to “...recapture some of the 'messiness' which the Kemmis version tends to gloss [over]” (Hopkins, 1985).

- The role of reflection

Another distinguishing characteristic of action research is the degree of empowerment given to all participants. Involvement is of a knowing nature, with no hidden controls or preemption of direction by the researcher. All participants including university
researchers, teachers and students negotiate meaning from the data and contribute to the selection of interventionary strategies. Elliott (1978; cited in Kemmis & McTaggart, 1990b) considers the need for communication between all participants to be of paramount importance:

Since action research looks at a problem from the point of view of those involved it can only be validated in unconstrained dialogue with them....Since action research involves unconstrained dialogue between "researcher" (whether he be an outsider or teacher/researcher) and the participants, there must be free information flow between them. (p. 122)

Perhaps the key component involved in action research is the notion of praxis. Action research is intended to be the reflective counterpart of practical diagnosis (Elliott, 1978; in MacIissac, 1996). Schon (1983; cited in MacIissac, 1996) describes the use of reflection to generate models from a body of previous knowledge. These models are used to re-frame a problem, and then experiments are performed to bring about outcomes which are subjected to further analysis. This model (called reflection-in-action) frames means and ends interdependently and recognises that there is little or no separation of research from practice, little or no separation of knowing and doing. Schon's model of reflection-in-action compliments the iterative and investigative natures of action research.

4.3.4 Principles of action research

What gives action research its unique flavour is the set of principles that guide the research. Winter (1989) provides a comprehensive overview of six key principles which are detailed below:

1. Reflexive critique

An account of a situation, such as notes, transcripts or official documents, will make implicit claims to be authoritative, i.e., it that it is factual and true. Truth in a social setting, however, is relative to the teller. The principle of reflective critique means people deliberately examine issues and thinking or data collection processes and make explicit the interpretations, biases, assumptions and concerns upon which
CHAPTER FOUR: METHODOLOGY AND DESIGN

judgments are made. In this way, practical accounts can give rise to theoretical considerations.

2. Dialectical critique
Winter (1989) posits that reality, particularly social reality, is consensually validated, which is to say it is shared through language. Phenomena are conceptualised in dialogue, therefore a dialectical critique is required to understand the set of relationships both between the phenomenon and its context, and between the elements constituting the phenomenon. The key elements to focus attention on are those constituent elements that are unstable, or in opposition to one another. These are the ones that are most likely to create changes.

3. Collaborative resource
Participants in an action research project are co-researchers. The principle of collaborative resource presupposes that each person's ideas are equally significant as potential resources for creating interpretive categories of analysis, negotiated among the participants. It strives to avoid the skewing of credibility stemming from the prior status of an idea-holder such as an instructor. It especially makes possible the insights gleaned from noting the contradictions both between many viewpoints and within a single viewpoint.

4. Risk
The change process potentially threatens all previously established ways of doing things, thus it may create psychic fears among the practitioners. One of the more prominent fears comes from the risk to ego stemming from open discussion of one's interpretations, ideas, and judgments. Initiators of action research attempt to allay others' fears and invite participation by pointing out that they, too, will be subject to the same process, and that whatever the outcome, learning will take place.

5. Plural Structure
The nature of the research embodies a multiplicity of views, commentaries and critiques, leading to multiple possible actions and interpretations. This plural structure of inquiry requires a plural text for reporting. This means that there will be many
accounts made explicit, with commentaries on their contradictions, and a range of options for action presented. A report, therefore, acts as a support for ongoing discussion among collaborators, rather than a final conclusion of fact.

6. Theory, Practice, Transformation

For action researchers, theory informs practice, practice refines theory, in a continuous transformation. In any setting, people's actions are based on implicitly held assumptions, theories and hypotheses, and with every observed result, theoretical knowledge is enhanced. The two are intertwined aspects of a single change process. It is up to the researchers to make explicit the theoretical justifications for the actions, and to question the bases of those justifications. The ensuing practical applications that follow are subjected to further analysis, in a transformative cycle that continuously alternates emphasis between theory and practice.

4.4 Procedure employed in the study

This section of the chapter discuss in depth the procedure employed in the research investigation, namely, the pilot questionnaire, the participants that took part in the investigation and the demographic profile of the population that was surveyed. I also discuss the methods of data collection, namely, questionnaires and interviews.

To re-cap, I wanted to investigate the effectiveness of incorporating collaborative learning methods in both face-to-face and computer-supported environments. This study also aimed to try and improve the overall learning of concepts in a collaborative and computer-supported environment. Further it sought to determine the attitude of students to this approach to learning. The design of the proposed research study included three methods of data collection - questionnaires administered at the end of the semester-long study, work done during the weekly tutorial and laboratory sessions, and interviews with students.
4.4.1 Pilot questionnaire

During the course of my PhD candidature, I was involved as a sessional lecturer in the teaching of mathematics subjects with the Department of Mathematical Sciences. This enabled a pilot study to be conducted with students enrolled in the *Mathematical Modelling for Science* (Subject Number: 33190) subject in autumn 2003 at the University of Technology, Sydney. The pilot questionnaire addressed students’ learning style preference and this was administered to approximately 290 students.

Overall, the students faced no major problems in regards to completing the questionnaire. Most of these students were from a non-English speaking background, yet they understood the instructions set out in the questionnaire. Consequently, no changes were made to the instruments that were developed and were used in their original form in the main study. Comprehension was one of the reasons for administering the pilot questionnaire and NESB is another determinant of understanding of wording. A decision was made to not use the data collected from this group but to collect and analyse data from the main study questionnaires only.

4.4.2 Participants in the study

The participants in the main study were engineering students who were enrolled in the first-year core mathematics subject, Mathematical Modelling 1 (Subject Number: 33130). A total of 436 students were enrolled in this subject, while 344 students consented to participate in the study. This equates to a 79% success rate.

4.4.3 Demographics profile

Demographic information in terms of age, gender, language spoken at home, and number of years spent in Australia was sought from the 344 students. Table 4.3a-d provides the summary statistics of the demographic information.

The majority of students surveyed were high-school leavers (coded as 1 in the table) who were in the age group of 17-19 years, while mature age students (coded as 2 in Table 4.3a) represented only 19% of the population sampled. This can be linked with
the length of stay in Australia, with 81% of the population having spent 6 or more years in the country (this category is coded as 2 in Table 4.3c: YRS denoting years) and only 18% having spent 5 or less years in the country (this category code as 1 in Table 4.3c). This means that the majority of the students recently undertook some form of study in an Australian school before advancing to university for higher studies and were therefore familiar with the Australian system of education. Below is a key for easy understanding of the four tables on the next page:

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Coding</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 4.3a (Age)</td>
<td>1</td>
<td>High school leavers</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Mature age students</td>
</tr>
<tr>
<td>Table 4.3b (Sex)</td>
<td>1</td>
<td>Male</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Female</td>
</tr>
<tr>
<td>Table 4.3c [Length of stay]</td>
<td>1</td>
<td>Recent immigrants</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Australian residents</td>
</tr>
<tr>
<td>Table 4.3d [Language]</td>
<td>1</td>
<td>English speakers</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Middle Eastern descent</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Asian &amp; Indian descent</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>European descent</td>
</tr>
</tbody>
</table>

Table 4.3a: Summary statistics of data collected and coded for age of students

<table>
<thead>
<tr>
<th>AGE</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>269</td>
<td>78.2</td>
<td>80.5</td>
<td>80.5</td>
</tr>
<tr>
<td>2.00</td>
<td>65</td>
<td>18.9</td>
<td>19.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>334</td>
<td>97.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>10</td>
<td>2.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>344</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.3b: Summary statistics of data collected and coded for gender of students

<table>
<thead>
<tr>
<th>SEX</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>304</td>
<td>88.4</td>
<td>88.9</td>
<td>88.9</td>
</tr>
<tr>
<td>2.00</td>
<td>38</td>
<td>11.0</td>
<td>11.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>342</td>
<td>99.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>2</td>
<td>.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>344</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.3c: Summary statistics of data collected and coded for number of years spent in Australia

<table>
<thead>
<tr>
<th>YRS</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid 1.00</td>
<td>61</td>
<td>17.7</td>
<td>18.0</td>
<td>18.0</td>
</tr>
<tr>
<td>2.00</td>
<td>277</td>
<td>80.5</td>
<td>82.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>338</td>
<td>98.3</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Missing System</td>
<td>6</td>
<td>1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>344</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.3d: Summary statistics of data collected and coded for language spoken at home

<table>
<thead>
<tr>
<th>LANG</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid 1.00</td>
<td>131</td>
<td>38.1</td>
<td>38.4</td>
<td>38.4</td>
</tr>
<tr>
<td>2.00</td>
<td>32</td>
<td>9.3</td>
<td>9.4</td>
<td>47.8</td>
</tr>
<tr>
<td>3.00</td>
<td>146</td>
<td>42.4</td>
<td>42.8</td>
<td>90.6</td>
</tr>
<tr>
<td>4.00</td>
<td>32</td>
<td>9.3</td>
<td>9.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>341</td>
<td>99.1</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Missing System</td>
<td>3</td>
<td>.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>344</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There were more male students in the study (coded as 1 in Table 4.3b), comprising 88% of the population with only 38 of the 344 students being female. The cultural background of students surveyed was very diverse as can be seen from the table. There were more non-English speakers (61%) than English speakers (38%) (coded as 1 in Table 4.3d: LANG denoting language), with 42% of the population representing students of Asian and Indian background (coded as 3 in Table 4.3d). Students of European background and Middle Eastern background each represented 9% of the population sample.

4.4.4 The questionnaires

There were four questionnaires that were administered to students. The first one was a questionnaire on tertiary students' preferred learning styles administered at the start of the investigation in autumn 2003. The second one was in two parts: Part I asked about students' opinions on the objectives for setting group work, while Part II asked for students' opinions about group work in mathematics - the benefits and shortcomings of doing group work in mathematics (see Appendix A4 for questionnaire). The third
CHAPTER FOUR: METHODOLOGY AND DESIGN

questionnaire sought students' attitudes towards using computers and the fourth questionnaire sought information regarding students' attitudes towards the assessment of group work. These three questionnaires were administered at the end of the teaching semester.

Each of the questionnaires was adapted from various sources and a more detailed explanation of each questionnaire along with the source will be outlined in the next four chapters, where the results and discussion of findings will also be described. Due to the fact that the questionnaire required students to disclose personal information about them, strict coding was required to guarantee anonymity. The names were only used at the data entry stage, where the individual responses were sequentially numbered.

4.4.5 The interviews

The second method of data collection involved interviews with twenty students who volunteered their time to talk about their views regarding group work in mathematics, the assessment of group work and other concerns they had. These students were from the large cohort who consented to participate in the research investigation. Interviews were audio-taped only and later transcribed for analysis. The interviews on average went for 30-40 minutes. As stated above, the students that volunteered were from the tutorial groups. I visited each tutorial group and asked for volunteers who would be interested to spend some time talking about the issues that were of interest to this project. Table 4.4 lists the questions asked in the interviews.

Table 4.4: Interview questions

1. What is your major in Engineering?
2. Why have you chosen to do an Engineering degree?
3. How are you finding mathematics so far?
4. How are you finding working in groups so far in this subject?
5. Does working in groups affect the way you're learning mathematics?
6. Are you involved in group work in any other subject this semester? If so, how do you find group work in that subject?
7. What do you think about the use of computers in learning mathematics?
8. Does using Mathematica help you understand the mathematics?
CHAPTER FOUR: METHODOLOGY AND DESIGN

9. How are you finding the tutorials and labs so far?

10. How do you find the structure of the sessions and the types of tasks assigned?

11. What are your opinions about assessment in mathematics in general?

12. How do you feel about the way you're assessed in MMI?

13. What are the best aspects of this subject so far?

14. What are the worst aspects of this subject so far?

15. Are you working on your own or in a group for your assignment? If in a group, are you working with the same members as in your tutorials?

16. Is there anything else you would like to add?

Table 4.5: Demographic features of students that were interviewed

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Gender</th>
<th>Age</th>
<th>Language Background</th>
<th>Length of stay in Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student I</td>
<td>Female</td>
<td>18</td>
<td>English</td>
<td>18</td>
</tr>
<tr>
<td>Student 2</td>
<td>Male</td>
<td>18</td>
<td>English</td>
<td>18</td>
</tr>
<tr>
<td>Student 3</td>
<td>Male</td>
<td>18</td>
<td>Burmese</td>
<td>14</td>
</tr>
<tr>
<td>Student 4</td>
<td>Male</td>
<td>18</td>
<td>Vietnamese</td>
<td>18</td>
</tr>
<tr>
<td>Student 5</td>
<td>Male</td>
<td>18</td>
<td>English</td>
<td>5</td>
</tr>
<tr>
<td>Student 6</td>
<td>Male</td>
<td>17</td>
<td>English</td>
<td>16</td>
</tr>
<tr>
<td>Student 7</td>
<td>Male</td>
<td>20</td>
<td>English</td>
<td>20</td>
</tr>
<tr>
<td>Student 8</td>
<td>Female</td>
<td>24</td>
<td>Burmese</td>
<td>4</td>
</tr>
<tr>
<td>Student 9</td>
<td>Male</td>
<td>18</td>
<td>Gujarati</td>
<td>16</td>
</tr>
<tr>
<td>Student 10</td>
<td>Male</td>
<td>19</td>
<td>Vietnamese</td>
<td>13</td>
</tr>
<tr>
<td>Student II</td>
<td>Male</td>
<td>18</td>
<td>English</td>
<td>14</td>
</tr>
<tr>
<td>Student 12</td>
<td>Female</td>
<td>18</td>
<td>Cantonese</td>
<td>11</td>
</tr>
<tr>
<td>Student 13</td>
<td>Male</td>
<td>20</td>
<td>English</td>
<td>20</td>
</tr>
<tr>
<td>Student 14</td>
<td>Male</td>
<td>18</td>
<td>Arabic</td>
<td>5</td>
</tr>
<tr>
<td>Student 15</td>
<td>Male</td>
<td>19</td>
<td>Vietnamese</td>
<td>17</td>
</tr>
<tr>
<td>Student 16</td>
<td>Male</td>
<td>18</td>
<td>Arabic</td>
<td>11</td>
</tr>
<tr>
<td>Student 17</td>
<td>Female</td>
<td>18</td>
<td>English</td>
<td>18</td>
</tr>
<tr>
<td>Student 18</td>
<td>Male</td>
<td>18</td>
<td>English</td>
<td>18</td>
</tr>
<tr>
<td>Student 19</td>
<td>Male</td>
<td>17</td>
<td>Bengali</td>
<td>11</td>
</tr>
<tr>
<td>Student 20</td>
<td>Male</td>
<td>18</td>
<td>English</td>
<td>18</td>
</tr>
</tbody>
</table>
Table 4.5 above outlines the demographic features of the students that were interviewed based on the four demographic variables of interest in this investigation. The table shows that 4 of the 20 students were female (20% representation). Three students were mature age students (15% representation) while the remaining 17 students were high school leavers. Ten out of the 20 students were of English speaking background, which means that 50% of the group were not of an English speaking background. Seventeen students (15% representation) were Australian residents with three students being recent immigrants to Australia.

4.5 Quality criteria

The importance of having quality data cannot be overemphasised. Romberg (1992) cites Larabees (1945), when he says:

\[
\text{anyone who has surveyed the long history of man's claims about knowing is struck by the discrepancy between the pretentiousness of most knowledge-claims and the small amount of evidence actually available to back them up.}
\]

\[\text{(Larabees, 1945, In Romberg, 1992, p58)}\]

It is important that the methods used in research are measured against a number of quality criteria. In particular the data needs to be reliable, valid, and preferably generalisable (Bogdan & Biklen, 1982), and the researcher should identify his/her own biases and ideologies (Janesick, 1994). Biases of a statistical nature, especially non-response in the case of questionnaires, also need to be identified. How these issues affect this particular study will now be discussed.

4.5.1 Bias

During the course of the project, I was an observer in the various tutorial groups and my involvement in the subject went no further than setting the tasks for collaborative activity. A possible source of bias comes from my personal belief prior to the research in the worth of collaborative tutorials, and hence a personal interest in the outcome of the research. Romberg (1992) considers that all scholars share this form of bias, in that a researcher must be personally interested in a phenomenon to be committed to
investigating questions about it, and that a disinterested scholar should not be trusted. What is more important is that the scholar exhibits objectivity in the manner of gathering and examining evidence, and reporting findings (Romberg, 1992).

An examination of the response rates to the questionnaires suggests two very important sources of bias, that of selection and non-response. A total of 344 responses were received to the questionnaire, out of a total of 436 students. This represents a 79% response rate to a questionnaire. While the percentage response rate could be attributed to the fact that students' participation was voluntary, the reason why students do not wish to participate must be considered. The students opting not to participate in the study as well as those who gave consent but did not respond, may well be different in some critical way to those responding. For instance, they may have totally different feelings toward mathematics in general, or collaborative learning in particular. However, given the reasonably high participation in the study (79% response rate) and that lack of significant difference in examination results, I believe that the group is representative.

Another possible source of bias may come from the efforts of both those students answering questionnaire items as well as those being observed to 'please' the researcher, either out of fear of repercussions in their assessment (despite strong assurances to the contrary), or just a natural inclination to do the right thing. Such biases are well documented in statistical studies, and are similar to what medical practitioners term the Hawthorne effect (see Roethlisberger & Dickson, 1939), where subjects under observation realise their role as guinea pigs: "In the initial stages of research, informants may dissemble, present an ideal self or tell the researcher what they think the researcher would, or wants to hear" (Bums, 1990, p. 247).

Other potential sources of bias in the questionnaires stem from such features as the wording of the questions (Bradburn & Sudman, 1991), which may be especially significant in the case when a number of students surveyed would consider English as their second language, and item non-response, where a respondent just leaves out a questions, either because they do not understand it or because they do not want to
answer. The NESB factor did not show up in the pilot study so it was not expected to be significant in the study.

Yet another source of bias may be in relation to my personal attributes and the reason why I decided to investigate the effects of age, sex, length of stay in Australia and language diversity. According to the way in which the variables are defined, I am a female mathematics lecturer, not born in Australia, a Native English speaker who has been in Australia for less than six years. So, for instance, a male mathematics person may not consider gender to be an important variable for investigation.

4.5.2 Reliability

Reliability is the extent to which a test or procedure produces similar results under constant conditions on all occasions (by an independent researcher) (Bogdan & Biklen, 1982). Different results could indicate that the research methodology has not been followed, or that the independent researcher has different interpretations of the results despite using the same procedures, which are both particularly likely in qualitative research because of the human element (Bums, 1990). However, Bogdan and Biklen (1982) downplay this effect by stating that qualitative researchers do not share the same expectation of reliability that quantitative researchers have and that, "...two researchers studying a single setting may come up with different data and produce different findings... both studies can be reliable" (Bogdan & Biklen, 1982, p44).

Only if conclusions were contradictory would the reliability of the studies be questioned. As well, there are measures that can enhance reliability, most if which are now commonplace in both qualitative and quantitative studies, such as complete and accurate description of the research process, the research questions, and the methods of data collection and analysis. This enables researchers to replicate more closely the same procedures in comparable settings. Furthermore, the reason for the research and any possible biases and assumptions must be included in the research report (Bums, 1990). For this particular research, the bias of me being in favour of collaborative group work has already been identified and I have attempted to address the other concerns as far as possible.
4.5.3 Validity

Validity refers to the degree to which the method of study achieves what it purports to discover (Oates, 1998). More simply, validity tells us whether an item measures or describes what it is supposed to measure or describe. If an item is unreliable, it must also lack validity (Bell, 1987). Since in a qualitative study the researcher is the instrument, it is important for the sake of validity that the researcher is rigorous, guards against bias, maintains neutrality and focuses on the entire group under study. It is for this reason that the interviews were limited to a certain number as responses would have started to get repeated after they were exhausted. The quantitative measures such as the questionnaires are easier to satisfy in terms of validity, but they too are subject to bias such as that stemming from the nature of the questionnaires themselves, both in the design, for instance question format and issues of non-response as identified earlier.

4.5.4 Generalisability

Generalisability refers to the extent to which a study's findings can be applied to other populations in other situations. As Bums (1990, p1!) warns in regard to observational studies: "contexts, situations, events, conditions, and interaction cannot be replicated to any extent nor can generalisations be made to a wider context than the one studied with any confidence". Bell (1987, p7) discusses the problems of having a single observer researcher, because of the subjectivity of selections made:

The researcher selects the area for study and decides which material to present in the final report: It is difficult to crosscheck information and so there is always the danger of distortion.

However, many researchers feel that the reliability of a case study is more important than its generalisability; single studies of events are worthwhile as long as a person in a similar situation is able to relate their decision making to that described in the case study (Bell, 1987). In the case of this research, whether generalisability is important is debatable. Certainly the findings may be of interest to other mathematics educators with an interest in using collaborative problem-solving methods, but the aim of the study is to determine the effectiveness of such methods for the learning of mathematics.
CHAPTER FOUR: METHODOLOGY AND DESIGN

However, the findings from the questionnaire may well be generalisable if the issues of non-response are addressed or taken into consideration in any inferences since the study was conducted over a large sample. A sample of students (344 out of a possible 436) who responded to the questionnaires comprises a statistically significant sample size to draw inferences from, as long as they are balanced against identified biases (Wild & Seber, 1996).

4.5.5 Triangulation of data

Triangulation is a commonly used technique to improve the validity of research and help eliminate the effects of or at least identify biases. Triangulation is defined as having two or more methods of data collection in the same study. It can be employed in both quantitative (validation) and qualitative (inquiry) studies. It is a method-appropriate strategy of finding the credibility of qualitative analyses. It becomes an alternative to traditional criteria like reliability and validity and often used in the social sciences because by combining multiple observers, theories, methods, and empirical materials, social scientists can attempt to address weaknesses or intrinsic biases and the problems that come from single method, single-observer, single-theory studies.

There are various types of triangulation and four are listed below:

a. data triangulation - involving time, space, and persons;
b. investigator triangulation - consisting of the use of multiple, rather than single, observers;
c. theory triangulation - which consists of using more than one theoretical scheme in the interpretation of the phenomenon;
d. methodological triangulation - which involves using more than one method and may consist of within-method or between-method strategies.

This project adopted methodological triangulation and the use of triangulation enhancing validity was selected:

...not only does using more than one method mirror the complexity of human behavior, it is also a check on validity when using a case study or similar approach, because of the notion of convergence independent measures of the same objective.

(Cohen & Manion, 1989)
However, while triangulation may address some of the identified biases, it is unfortunately unlikely to address that of those students who did not respond to the questionnaire.

4.6 Synopsis of chapter

This chapter has described how the actual research was carried out, with the aim of allowing for close replication of the study if desired. Issues underpinning the methodology of the study were examined, with a discussion of the relative merits of quantitative and qualitative methods. The conclusion was reached that the debate itself is somewhat spurious in that it is the quality of the research that is of paramount importance not necessarily the individual methods being employed.

A case was put for multiple perspectives and it was shown that both quantitative and qualitative methods can be employed to measure the same phenomena and indeed each can each complement the usefulness of the other. Next the process of selecting the specific methods used was described, with consideration given to an appropriate balance of quantitative and qualitative methods. A method was used which employed a mixed-method approach to research, in line with the technique of triangulation.

The criteria considered in selecting the specific methods were stated and how each selected method satisfied these criteria was described. In the next section the actual research process. was described, including a description about the different questionnaires that were administered, and the interview questions used.

The chapter finished off by examining issues of quality of evidence. Sources of bias and ways of ensuring reliability and validity were identified and discussed and it was concluded that the possibility of generalisability from this study was unlikely. The findings from this study will now be detailed in chapters five, six, seven and eight before returning to some of the issues outlined in this chapter such as response rates and bias when discussing the findings in chapter nine.
5.1 Introduction

This chapter presents the results and discussion of findings from the learning style preference questionnaire that was administered to students at the end of the Autumn Semester in 2003. The questionnaire was adapted from the one designed by Reid (1984) (see Appendix A4. She called it the Perceptual Learning Style Preference Questionnaire (PLSPQ). The understanding is this: people learn in many different ways. For instance, some people learn primarily with their eyes (visual learners) or with the ears (auditory learners); others prefer to learn by experience and/or 'by hands-on' tasks (kinesthetic or tactile learners); and some learn better when they work alone, others in groups. The questionnaire was administered to students to identify the ways they best learnt, the ways they preferred to learn. The questionnaire was originally designed for students in an EFL\(^1\) classroom and I decided to use this questionnaire because the majority of the students in this study were non-Native English speakers. The research questions posed in this chapter are:

1. What are tertiary students' preferred learning styles?
2. What impact do the demographic variables have on students' preference for learning?

\(^1\) English as a Foreign Language - EFL
5.2 Collection of data

As described in Chapter Four, 344 first-year engineering students studying a core mathematics subject took part in this study. They worked on carefully designed collaborative group tasks during their set tutorial times and computer laboratory classes throughout autumn 2003. In all, there were 16 groups each with 20-25 students on average. These groups ran at different times during the week in a number of different classrooms. When students got to their individual classrooms, they were instructed to move furniture around to ease discussion with the other member in their group. Students were evaluated on the work they produced during these tutorial and laboratory sessions.

Students also completed a questionnaire at the end of semester on their, their attitudes towards using computers, their attitudes towards group-based assessment, and reactions towards group work in mathematics. Finally, twenty students volunteered to be interviewed (interviews lasted 40 minutes on average) during 2003 to talk about their opinions on collaborative learning, working with Mathematica and assessment concerns. The interviews were audio taped and transcribed later.

5.3 Analysis and results

This section of the chapter presents the statistical analysis and results of the questionnaire data and interview transcripts, and will also discuss the findings of the study in relation to existing literature in the area.

5.3.1 Learning style preference questionnaire (LSPQ) (Reid, 1984)

Students responded to 30 items, which asked about their preferred learning style by circling the number on a five-point scale (where "1 = strongly disagree", "2 = disagree", "3 = neutral", "4 = agree", and "5 = strongly agree") that best reflected their perceptions (see Appendix A4 for questionnaire items used). The 30 items fell into six learning style categories: Auditory, Group, Individual, Kinaesthetic, Tactile, and Visual learning styles. However, since my interest was in investigating the effects of collaborative
learning methods in mathematics only 10 of the 30 items in the questionnaire were used, that is, those relating to the *individual* and *group* learning style.

A principal component factor analysis\(^2\) with varimax rotation of 10 items generated 2 constructs or factors, namely, *Individual-based Learning Preference* and *Group-based Learning Preference* (see Table 5.1 for output). This two-factor model accounted for 62% of the item variation (adjusted \(R^2 = 62.43\)). In other words, learning style preference accounted for over half of the variance in gains. The internal consistency reliability was reasonably high for all six factors, with Cronbach's alpha of 0.7945. Cronbach's alpha is a measure of strength, where 1.0 suggests a perfect correlation. Figure 5.1 shows the scree plot\(^3\) of the two factors obtained from the factor analysis and Table 5.2 displays the rotated component matrix for the two factors. Questionnaire items 3, 4, 5, 21 and 23 fell under the Group-based Learning Preference factor while questionnaire items 13, 18, 27, 28 and 30 fell under the Individual-based Learning Preference factor. Figures 5.2a-e are histogram plots of each of the 5 items that make up the collaborative learning style preference while figures 5.3a-e are histogram plots of each of the 5 items that make up the individual learning style preference.

### Table 5.1: Principal component factor analysis for learning style preference

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction Sums of Squared Loadings</th>
<th>Rotation Sums of Squared Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of Variance</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>1</td>
<td>4.925</td>
<td>49.247</td>
<td>49.247</td>
</tr>
<tr>
<td>3</td>
<td>.922</td>
<td>9.218</td>
<td>71.649</td>
</tr>
<tr>
<td>4</td>
<td>.745</td>
<td>7.452</td>
<td>79.101</td>
</tr>
<tr>
<td>5</td>
<td>.473</td>
<td>4.732</td>
<td>83.832</td>
</tr>
<tr>
<td>6</td>
<td>.405</td>
<td>4.047</td>
<td>87.879</td>
</tr>
<tr>
<td>7</td>
<td>.345</td>
<td>3.447</td>
<td>91.326</td>
</tr>
<tr>
<td>8</td>
<td>.334</td>
<td>3.343</td>
<td>94.670</td>
</tr>
<tr>
<td>10</td>
<td>.249</td>
<td>2.485</td>
<td>100.000</td>
</tr>
</tbody>
</table>

**Extraction Method:** Principal Component Analysis.

---

\(^2\) Factor analysis is a statistical technique used to summarise large amounts of data and identify relationships among multiple variables. Rotation is used to rotate the axes of a scatter plot to maximise the variance between the factors (i.e. to maximise the difference between factors).

\(^3\) A scree plot is a simple line segment plot that shows the fraction of total variance in the data as explained or represented by each principal component. The principal components are ordered, and by definition are therefore assigned a number label, by decreasing order of contribution to total variance. Such a plot when read left-to-right across the abscissa can often show a clear separation in fraction of total variance where the 'most important' components cease and the 'least important' components begin. The point of separation is often called the 'elbow'.
CHAPTER FIVE: STUDY I - LEARNING STYLE PREFERENCES

Figure 5.1: Scree plot

Table 5.2: Rotated component matrix of the two factors

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q4</td>
<td>.855</td>
<td>-.193</td>
</tr>
<tr>
<td>Q5</td>
<td>.846</td>
<td>-.181</td>
</tr>
<tr>
<td>Q3</td>
<td>.791</td>
<td>-.204</td>
</tr>
<tr>
<td>Q23</td>
<td>.623</td>
<td>-.348</td>
</tr>
<tr>
<td>Q21</td>
<td>.622</td>
<td>-.302</td>
</tr>
<tr>
<td>Q13</td>
<td>-6.93E-02</td>
<td>.784</td>
</tr>
<tr>
<td>Q30</td>
<td>-.355</td>
<td>.783</td>
</tr>
<tr>
<td>Q18</td>
<td>-.346</td>
<td>.743</td>
</tr>
<tr>
<td>Q27</td>
<td>-.200</td>
<td>.720</td>
</tr>
<tr>
<td>Q28</td>
<td>-.290</td>
<td>.634</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
   a. Rotation converged in 3 iterations.
CHAPTER FIVE: STUDY 1 - LEARNING STYLE PREFERENCES

Figure 5.2a-e: Histogram of responses to questionnaire items relating to the collaborative learning style

The figure above shows the histogram plots for the five questionnaire items relating to the collaborative learning style. The mean scores for questionnaire items 3, 4, 5, 21, and 23 are 3.3, 3.4, 3.4, 3.5, and 3.3 respectively.
CHAPTER FIVE: STUDY 1 - LEARNING STYLE PREFERENCES

The figure above shows the histogram plots for the five questionnaire items relating to the individual learning style. The mean scores for questionnaire items 13, 18, 27, 28, and 30 are 3.6, 3.4, 3.1, 3.0, and 3.2 respectively.
CHAPTER FIVE: STUDY I - LEARNING STYLE PREFERENCES

Figures 5.4 and 5.5 are histogram plots of the two dimensions (or factors) obtained from the factor analysis. CoUab represents the mean score for dimension/factor 1 (namely, group-based learning preference) for each student, while Solo represents the mean score for dimension/factor 2 (namely, individual-based learning preference). There was not much of a statistical difference in the average score for each of the two factors, with the mean score for CoUab being 3.4 and the mean score for Solo being 3.3.

**Figure 5.4: Histogram of Dimension 1 (CoUab) Scores**

**Figure 5.5: Histogram of Dimension 1 (Solo) Scores**
CHAPTER FIVE: STUDY I - LEARNING STYLE PREFERENCES

Figures 5.6, 5.7, 5.8 and 5.9 are scatter plots of CoUah (average score of the five items in dimension 1) versus Solo (average score of the five items in dimension 2) respectively with markers set by age, gender, number of years spent in Australia and language spoken at home.

Figure 5.6: Scatter plot of the two dimensions plotted against each other with markers set by age

Figure 5.7: Scatter plot of the two dimensions plotted against each other with markers set by sex
CHAPTER FIVE: STUDY I – LEARNING STYLE PREFERENCES

Figure 5.8: Scatter plot of the two dimensions plotted against each other with markers set by number of years in Australia

Figure 5.9: Scatter plot of the two dimensions plotted against each other with markers set by language spoken at home
CHAPTER FIVE: STUDY I-LEARNING STYLE PREFERENCES

Each of the four scatter plots of CoUab versus Solo above show a fairly strong negative relationship for age, gender, length of stay and language spoken at home. The dimensions are not sufficiently independent, which is not a desirable result since we were trying for independent dimensions. Next, a multivariate test using the general linear model (namely, MANOVA, which stands for multivariate analysis of variance) was performed using the actual factor scores for the two dimensions as the dependent variables and age, sex, number of years, and language spoken as fixed factors (see Table 5.3 for output). The analysis shows that lang is marginally significant ($p = 0.053$).

Table 5.3: Multivariate test for the two dimensions using age, sex, number of years and language spoken as fixed factors

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillai's Trace</th>
<th>F</th>
<th>HVDof thesis df</th>
<th>Error df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>.087*</td>
<td>2.000</td>
<td>309.000</td>
<td>.917</td>
</tr>
<tr>
<td></td>
<td>Wilks' Lambda</td>
<td>.999</td>
<td>2.000</td>
<td>309.000</td>
<td>.917</td>
</tr>
<tr>
<td></td>
<td>Hotelling's Trace</td>
<td>.001</td>
<td>.087*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td></td>
<td>Roy's Largest Root</td>
<td>.001</td>
<td>.087*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td>AGE</td>
<td>Pillai's Trace</td>
<td>.011</td>
<td>1.673*</td>
<td>2.000</td>
<td>.189</td>
</tr>
<tr>
<td></td>
<td>Wilks' Lambda</td>
<td>.989</td>
<td>1.673*</td>
<td>2.000</td>
<td>.189</td>
</tr>
<tr>
<td></td>
<td>Hotelling's Trace</td>
<td>.011</td>
<td>1.673*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td></td>
<td>Roy's Largest Root</td>
<td>.011</td>
<td>1.673*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td>SEX</td>
<td>Pillai's Trace</td>
<td>.004</td>
<td>.620*</td>
<td>2.000</td>
<td>.539</td>
</tr>
<tr>
<td></td>
<td>Wilks' Lambda</td>
<td>.996</td>
<td>.620*</td>
<td>2.000</td>
<td>.539</td>
</tr>
<tr>
<td></td>
<td>Hotelling's Trace</td>
<td>.004</td>
<td>.620*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td></td>
<td>Roy's Largest Root</td>
<td>.004</td>
<td>.620*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td>YEARS</td>
<td>Pillai's Trace</td>
<td>.004</td>
<td>.636*</td>
<td>2.000</td>
<td>.530</td>
</tr>
<tr>
<td></td>
<td>Wilks' Lambda</td>
<td>.996</td>
<td>.636*</td>
<td>2.000</td>
<td>.530</td>
</tr>
<tr>
<td></td>
<td>Hotelling's Trace</td>
<td>.004</td>
<td>.636*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td></td>
<td>Roy's Largest Root</td>
<td>.004</td>
<td>.636*</td>
<td>2.000</td>
<td>309.000</td>
</tr>
<tr>
<td>LANG</td>
<td>Pillai's Trace</td>
<td>.040</td>
<td>2.084</td>
<td>6.000</td>
<td>.053</td>
</tr>
<tr>
<td></td>
<td>Wilks' Lambda</td>
<td>.961</td>
<td>2.083*</td>
<td>6.000</td>
<td>.053</td>
</tr>
<tr>
<td></td>
<td>Hotelling's Trace</td>
<td>.041</td>
<td>2.083</td>
<td>6.000</td>
<td>616.000</td>
</tr>
<tr>
<td></td>
<td>Roy's Largest Root</td>
<td>.031</td>
<td>3.238*</td>
<td>3.000</td>
<td>310.000</td>
</tr>
</tbody>
</table>

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.
c. Design: Intercept+AGE+SEX+YEARS+LANG

Table 5.4a-d gives the estimated marginal means for the regression factor scores for the two dimensions, CoUab and Solo set by age, sex, number of years in Australia and language spoken at home while Table 5.5a-d gives estimated marginal means for the two dimensions, CoUab and Solo set by each of the four demographic variables.
Table 5.4a-d: Estimated marginal means for regression factor score for the two dimensions by age, sex, number of years and language spoken respectively

1. AGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>AGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>high school leavers</td>
<td>.104</td>
<td>.122</td>
<td>-1.36</td>
<td>.344</td>
<td></td>
</tr>
<tr>
<td>mature age students</td>
<td></td>
<td>-.166</td>
<td>.152</td>
<td>-1.465</td>
<td>.134</td>
<td></td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>high school leavers</td>
<td>-6.78E-02</td>
<td>.123</td>
<td>-1.309</td>
<td>.174</td>
<td></td>
</tr>
<tr>
<td>mature age students</td>
<td></td>
<td>-6.62E-03</td>
<td>.153</td>
<td>-1.308</td>
<td>.295</td>
<td></td>
</tr>
</tbody>
</table>

2. SEX

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>SEX</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>male</td>
<td>-3.82E-02</td>
<td>.094</td>
<td>-1.224</td>
<td>.147</td>
<td></td>
</tr>
<tr>
<td>female</td>
<td></td>
<td>-2.37E-02</td>
<td>.183</td>
<td>-1.383</td>
<td>.336</td>
<td></td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>male</td>
<td>6.145E-02</td>
<td>.095</td>
<td>-1.125</td>
<td>.248</td>
<td></td>
</tr>
<tr>
<td>female</td>
<td></td>
<td>-.136</td>
<td>.184</td>
<td>-1.497</td>
<td>.226</td>
<td></td>
</tr>
</tbody>
</table>

*REGR factor score 1 for analysis 1 ≡ regression factor score for CoUah dimension
REGR factor score 1 for analysis 2 ≡ regression factor score for Solo dimension
There was no significant difference in the means for either of the two dimensions across the two age groups, the two gender groups or even between recent immigrants and Australian residents. However, with respect to language spoken at home, results were interesting as indicated by the marginally significant p-value. There was a 0.3 difference in the mean score of Middle Eastern students (3.4) and European students (3.1) in the
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CoUab dimension, indicating that European students had a higher preference for the group learning style. In the Solo category, there was a 0.3 difference in the mean score of English speakers (3.2) and Middle Eastern students (3.5); in this case the latter group indicated a preference for learning individually.

In reference to the definition of the two dimensions, I also used an actual linear combination of questions as defined by the factor analysis, and histogram plots as well as scatter plots of the new scores, namely regfe_eo (regression factor scores for CoUab) and regfe_so (regression factor scores for Solo) with markers set by age, sex, number of years and language spoken were plotted (see figures 5.10 and 5.11 for the histogram plots and figures 5.12, 5.13, 5.14 and 5.15 for the scatter plots). This time the two dimensions produce a graph that is much more like two independent variables should be, namely, independent.

![Histogram of the regression factor scores for the CoUab dimension](image)

Figure 5.10: Histogram of the regression factor scores for the CoUab dimension

---

5 A linear combination of questions involves taking an average score of questions after reversing items that are negatively worded.
Figure 5.11: Histogram of the regression factor scores for the Solo dimension

Figure 5.12: Scatter plot of the regression scores of the two dimensions plotted against each other with markers set by age
CHAPTER FIVE: STUDY I - LEARNING STYLE PREFERENCES

Figure 5.13: Scatter plot of the regression scores of the two dimensions plotted against each other with markers set by sex

Figure 5.14: Scatter plot of the regression scores of the two dimensions plotted against each other with markers set by number of years in Australia
5.4 Discussion of findings

The results for students' preference for learning styles are not entirely surprising. The factor analysis as mentioned before produced two constructs: Dimension 1 - *Group-based Learning Style* (items 3, 4, 5, 21, and 23) and Dimension 2 - *Individual-based Learning Style* (items 13, 18, 27, 28, and 30). The mean scores for both dimensions (namely CoUab and Solo) were calculated and results were sorted by age, sex, number of years and language spoken, the results of which are summarised in the tables below. A numerical comparison was done between the CoUab and Solo scores and the results are displayed in Table 5.6.

The table shows that that mature age students have a strong preference for working individually (58%) as opposed to working with other students in a group environment. High-school leavers, on the other hand, seem to indicate a preference for working in groups instead of by themselves (52%), but the difference is not great. One reasoning
for this is perhaps that younger students are more open to new methods of learning and delivery as opposed to students of mature age.

Table 5.6: Data summary statistics by age

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>%</th>
<th>Collab &gt; Solo (^6)</th>
<th>Solo &gt; Collab (^7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>High-school leavers (1)</td>
<td>269</td>
<td>88</td>
<td>139</td>
<td>52</td>
</tr>
<tr>
<td>Mature age students (2)</td>
<td>65</td>
<td>11</td>
<td>27</td>
<td>42</td>
</tr>
</tbody>
</table>

There was a strong preference (61%) towards the group-based learning style for female students compared with only 48% of male students preferring such a learning style (see Table 5.7). This finding supports the literature findings that girls prefer to learn in a collaborative environment. It can also be inferred that boys do not have strong preferences for either individual based work (48%) or group based work (52%) and are able to work in both environments.

Table 5.7: Data summary statistics by sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>N</th>
<th>%</th>
<th>Collab &gt; Solo</th>
<th>Solo &gt; Collab</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Male (1)</td>
<td>304</td>
<td>78</td>
<td>147</td>
<td>48</td>
</tr>
<tr>
<td>Female (2)</td>
<td>38</td>
<td>19</td>
<td>23</td>
<td>61</td>
</tr>
</tbody>
</table>

In relation to the number of years students had spent in Australia (Table 5.8), recent immigrants, i.e. students who had been in Australia for 5 years or less, appear to favour working in groups rather than on their own (54% versus 46%). There appeared to be no significant difference in learning style preference for students who have spent 6 years or more in Australia which indicates that they would be comfortable learning in either environment.

\(^6\) Data summary for instances where the average score for collaborative learning preference (Collab) was higher than preference for learning individually (Solo).
\(^7\) Data summary for instances where the average score for individual learning preference (Solo) was higher than preference for learning in groups (Collab).
CHAPTER FIVE: STUDY I - LEARNING STYLE PREFERENCES

Table 5.8: Data summary statistics by number of years in Australia

<table>
<thead>
<tr>
<th>Number of Years</th>
<th>N</th>
<th>%</th>
<th>Collab &gt; Solo</th>
<th>N</th>
<th>%</th>
<th>Solo &gt; Collab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent immigrants (1)</td>
<td>61</td>
<td>18</td>
<td>33</td>
<td>54</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Australian residents (2)</td>
<td>277</td>
<td>81</td>
<td>134</td>
<td>48</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>

Finally, in relation to students’ cultural background and language spoken at home, the results were quite interesting (see Table 5.9). There was no difference in learning style preference for English speakers and little difference for students of Asian and Indian background, with 52% preferring to work in groups and 48% preferring to work by themselves. On the other hand, European students indicated a stronger preference for group-based learning while students from a Middle Eastern background had very strong preferences to work individually (63%) as opposed to working with other students in a group setting (38%). This is a very interesting finding. Possible reasoning for this is familiarity with working alone, and/or not wanting to work with others with whom they are not comfortable.

Table 5.9: Data summary statistics by language spoken at home

<table>
<thead>
<tr>
<th>Language Spoken</th>
<th>N</th>
<th>%</th>
<th>Collab &gt; Solo</th>
<th>N</th>
<th>%</th>
<th>Solo &gt; Collab</th>
</tr>
</thead>
<tbody>
<tr>
<td>English (1)</td>
<td>131</td>
<td>38</td>
<td>65</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Middle Eastern (2)</td>
<td>32</td>
<td>9</td>
<td>12</td>
<td>38</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Asian (3)</td>
<td>146</td>
<td>42</td>
<td>76</td>
<td>52</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>European (4)</td>
<td>32</td>
<td>9</td>
<td>17</td>
<td>53</td>
<td>53</td>
<td></td>
</tr>
</tbody>
</table>

5.5 Synopsis of chapter

This chapter looked at the data on students’ preferences for learning and the effects of age, gender, language background and length of stay in Australia on students’ preferences. The results obtained were interesting in certain regards. The difference in the mean scores were not statistically significant with the mean score for the collaborative learning style preference being 3.4 and the mean score for the individual
learning style preference being 3.3. The scatter plots of the two dimensions plotted against each other with markers set by each of the four variables of interest displayed a negative relationship. The multivariate analysis of variance (MANOVA) produced statistically significant results for language spoken at home (p-value = 0.053). The marginal means for the two dimensions showed that Middle Eastern students had a stronger preference for working alone (mean = 3.5). European, Asian and Indian students showed a greater preference for working together with other people (mean = 3.4). This result was quite surprising because it was expected the Asian and Indian students would prefer to work individually. It can be speculated that, as compared to European, Asian and Indian students as well as Native English speakers, Middle Eastern students appear to be resistant because they seem to be dependent or nonverbal emotionally.

Middle Eastern students may require more structure than students from other language backgrounds, may seek more definitive instruction and judgment of their work, may prefer to be considered one of a group, and will not as readily push themselves forward to seek information as will probably students from other language backgrounds. There were no significant differences in students' preferred learning style across the two age groups - high school leavers and mature age students, or across gender or migrant status.

A different analysis was also done in regards to the number of instances where the mean score for the CoUab dimension was greater (or less) than the mean score for the Solo dimension. The results were tabulated in Tables 5.6-5.9 and sorted by the four variables of interest. In relation to age, of the 65 mature age students, 58% indicated that they preferred to work individually. High-school students showed no statistically significant preference for either individual or collaborative learning styles.

In relation to gender, of the 38 females that participated in the study, 61% indicated a stronger preference for collaborative learning. Although this result is not statistically significant, the finding supports previous literature in that girls favour collaborative learning methods. While there have certainly been gains made in gender equity in Australian higher education, and there have been some increases in women's
participation in non-traditional areas, an analysis of the most recent student enrolment data shows that gender equity in the Australian higher education is yet to be achieved (Carrington & Pratt, 2003).

Regarding those students with migrant status, a majority of whom had spent more than 5 years in Australia, there was no statistically significant difference in learning style preference. This indicates that whether or not students were familiar with the Australian education system, their preference for learning was not particularly aligned towards either individual-based or group-based work. These findings are consistent with the results obtained from the MANOVA.

In summary, the findings from this study are listed below:

a. Mature students prefer to work individually.
b. Female students prefer to work in collaborative groups.
c. Students who recently immigrated to Australia also prefer working in groups.
d. Students of European descent prefer group-based work, while students of Middle-Eastern descent prefer to work individually.

Changing the perception of learning in engineering is important. Individual, hard or technical approaches to learning mathematics may not be attractive to women or indeed many men for that matter. Changing the perception of learning mathematics may encourage more women to consider engineering, but practical support such as access to equity scholarships for women of low SES backgrounds will be needed. Achieving equity is important because of its implications for equity in the workforce. Gender, cultural and other forms of equity also have implications for the quality and strength of our higher education system because diversity is central to educational quality and equity is central to diversity. In other words, interplay between quality, equity and diversity in higher education is essential.
Chapter 6

Study Two: Students' Views about group-based work and their perceptions about the objectives of setting group work: Results and analysis of findings

6.1 Introduction

This chapter presents the results and discussion of findings from the interviews conducted with the twenty students who volunteered their time. Students' quotes are used to substantiate research findings. This chapter also looks at the results from the questionnaire that sought students' opinions about the objectives for setting group work. The findings from the interviews and the questionnaire will be discussed in two parts. The research questions posed in this chapter are as follows:

1. What are tertiary students' views about group work?
2. What does age, gender, number of years spent in Australia and language spoken have on students' perceptions of the objectives for setting group work?
6.2 Part I: Students' views about group work

This chapter presents findings of issues and difficulties that students have with group work, and their opinions about assessment of group work in mathematics. Data is presented from in-depth interviews conducted with volunteers. The next section presents a thematic analysis of various benefits of collaborative-based learning which was published in D'Souza and Wood (2003e).

Nelson-LeGall (1992) captures the nature of cooperative learning when she states that "learning and understanding are not merely individual processes supported by the social context; rather they are the result of a continuous, dynamic negotiation between the individual and the social setting in which the individual's activity takes place. Both the individual and the social context are active and constructive in producing learning and understanding" (p52). The results presented here will be discussed in comparison to findings of past literature to illustrate how the current study links with the general literature on collaborative learning. These links clearly show that previous findings in other contexts have been born out in the tertiary mathematics context thus bringing out a triangulation of results with previous literature.

6.2.1 Collaborative discussions improve students' recall of text content (Dansereau, 1985; Slavin & Tanner, 1979)

Students working together are actively engaged in the learning process instead of passively listening to the teacher present information. Pairs of students working together represent the most effective form of interaction, followed by groups consisting of three or four members (Schwartz & Reisberg, 1991). When students in groups, some members are listening while the others are discussing the question under investigation. All in the group are developing valuable problem-solving skills by formulating their ideas, discussing them, receiving immediate feedback and responding to questions and comments from their partner (Johnson, 1973; 1974a). The interaction is continuous and all students are engaged during the session. Compare this situation to the lecture class where students may or may not be involved by listening to the teacher or by taking notes (Cooper et al., 1984). Slavin (1991) emphasises that "students will learn from one
CHAPTER SIX STUDY II-ATTITUDES TOWARDS GROUP WORK

another because in their discussions of the content, conflicts arise, inadequate reasoning will be exposed, will occur, and higher quality understandings emerge” (p.162).

[Quote from student]: It gets into my head more because if you talked about a certain question with your friends and you've discussed about it and you'll remember the formulas more and I guess it's more of a non-verbal learning kind of thing because the more you see something, the more you remember it and talking to someone about it makes me remember more.

6.2.2 Builds self-esteem in students (Johnson & Johnson, 1989)

Collaborative efforts among students result in a higher degree of accomplishment by all participants as opposed to individual, competitive systems in which many students are left behind (Slavin, 1990). Competition fosters a win-lose situation where more mathematically able students reap all the rewards and recognition and low-achieving students reap none. In contrast, students benefit from a collaborative learning environment in the sense that they help each other and in doing so build a supportive community which raises the performance level of each member. This in turn leads to higher self-esteem in all students (Webb, 1982).

[Quote student]: You can share ideas and like the saying goes ‘two heads are better than one’... takes a lot of pressure off yourself like if you're not particularly strong in one field and then you can help contribute in other ways and produce better results than you do by yourself

6.2.3 Develops higher level thinking skills (Webb, 1982)

When students read a text together, explain concepts to each other, and evaluate each other's explanations they engage in a high level of critical thinking. They frame the new concepts by using their own vocabulary and by basing their comments upon their previous knowledge. Thus, they construct a new knowledge base on top of their existing base. This process leads to deeper understanding and greater likelihood that they will retain the material longer than if they worked alone and simply read and reread the text.
CHAPTER SIX STUDY II - ATTITUDES TOWARDS GROUP WORK

[Quote from student]: I found it really helpful because they can explain stuff to you and help you understand it... now it's kind of helping because if I didn't understand something, another person could explain it in their own words - rather than me reading a textbook, they can show me with an example or something which I found helpful.

6.2.4 Collaborative learning creates an environment of active, exploratory learning (Slavin, 1990)

The entire focus of collaborative learning is to actively involve students in the learning process. Whenever students attempt to solve a problem or answer a question they become involved in the process of exploratory learning. They interact with each other, share ideas and information, seek additional information, make decisions about the results of their deliberations and present their findings to the entire class. They may tutor their peers or receive tutoring. This is a level of student empowerment that is unattainable with a lecture format or even with a teacher-led whole class discussion.

[Quote from student]: ... it's a lot more beneficial I think because you get more out of it because if you're there by yourself you only get your point of view as opposed to if you've got four of you working on something... you can sort of also say 'why don't you try this method or whatever?' ... and usually you get further in the long run.

[Quote from student]: I think it's a good idea working in groups because you get so many different inputs, and, because you know they are going to have the same problem... whereas when just teacher versus student relationship, I think everyone is sort of singular and you're not all at the same level, because when you're in a group, you all have the same problem and you all don't understand how to do a certain problem, you can all work together.

6.2.5 Collaborative learning fosters working together with peers (Schunk & Hanson, 1985)

Students often learn more by listening to their peers than they do by listening to an authority figure like a teacher. Peers often have a better understanding of what other students do not know or what causes them difficulty than the instructor does. The focus is on the student, not the instructor or tutor. In addition to shifting responsibility for learning onto students, collaborative learning provides an opportunity for students to
demonstrate their knowledge by helping their peers (Bargh & Schul, 1980), an important advantage over the lecture method or class discussion form of teaching.

[Quote from student]: ... I can compare this with learning at school...you can get your problems answered straightaway while it's fresh in your mind or if you don't understand something – you can work like a peer sort of thing helping you rather than like the teacher - it's probably a bit more comfortable, because then sometimes with like a high authoritative figure, you sort of don't tend to ask him all the stuff that you don't know, yeah, like someone sort of at your level - sort of ask him things that you wouldn't ask maybe like a teacher.

6.2.6 Weaker students improve their performance when grouped with higher achieving students (Cohen, 1994)

Swing and Peterson (1982) found that students of low achievement benefited from participation in groups heterogeneously composed in comparison to participation in homogeneous low-achieving groups (Cohen 1994). One reason for the improvement may be explained by the intense one-on-one tutoring which is possible with collaborative learning (Felder & Brent, 1994). Bums (1990) also suggests that with collaborative learning there is no waiting for help because it is available from other students or the tutor who circulates among the groups. In addition, students are directed to seek help from each other before asking the tutor. Another explanation offered by Johnson and Johnson (1990) is that weaker students are given the opportunity to model the reasoning processes of stronger students as well as preparing each other for tests, checking and correcting homework and helping each other see alternatives.

[Quote from student]: I think it pretty good - if people in your group know what they're doing, they can explain it everyone else and so, if the tutor doesn't have time to go around to everyone, you can sort of you know find out your own like resolve your own problems like within that time rather than wait for the tutor to come round to you like you know you save time.
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[Quote from student]: I'm doing well in them but I have a lot to thank for my group for that because my maths isn't as good as what it should be - I find that my group is pulling me up and I am achieving good results ... like I am actively putting in and helping do questions but I find that I wouldn't get anywhere near as a good a result without my group.

6.2.7. Collaborative learning provides stronger students with the deeper understanding that comes only from teaching material (cognitive rehearsal) (Felder & Brent, 1994)

The process of explaining one's reasoning creates a higher level of conceptual understanding and promotes critical thinking skills. In studies on the nature of interactions in collaborative learning and regular classes Cohen (1994) reports that the most consistent, positive predictor of achievement in these studies is the giving of detailed, elaborate explanations (Webb, 1980). In other words, the student who does the explaining is the student who benefits, compensating for how well he or she would have done based on past achievement/ability. Swing and Peterson (1982) also found that high achievers benefited from participation in heterogeneous groups, especially by giving explanations to others.

[Quote from student]: If one of my partners or peers, someone in my group, doesn't know how to do something and like I explain it to them how to do it, they learn and if I can explain how the question's done I learn, because I'm actually explaining, therefore it makes me feel that I know the question, I know what's going on, so, if I can explain it, that means I know it and then I can teach them at the same time.

6.2.8 Students explore alternative problem solutions in a safe environment (Sandberg, 1995)

Many students are hesitant to speak out and offer opinions publicly in a traditional classroom setting for fear of appearing foolish.

[Quote from student]: If I don't understand it and I'm not the only one, who doesn't understand it - I feel a bit intimidated to say 'Hey, can you explain that to me'...
CHAPTER SIX. STUDY II – ATTITUDES TOWARDS GROUP WORK

When students work in groups, solutions come from the group rather than from the individual. In essence, the focus is removed from the individual, thus diffusing the effects of criticism, even constructive criticism, from anyone student. Students can propose ideas and theories to their peers prior to formulating a final response, and then rehearse their presentation in an informal setting. If a group response is the end product, then the entire team becomes responsible for the answer.

[Quote from student]: I think it does because sometimes when you’re doing the question and you get stuck for a while you need another opinion, you need a fresh look on things and you can only get that if someone else just looks at it and sees it a different way so I find that’s helpful, also we all have different strengths - that applies to different parts of mathematics as well... so you can combine that so that you can complete the required questions in time.

Collaborative learning creates a safe, nurturing environment, where students can express themselves and explore their ideas without the fear of failure or criticism. In a lecture setting, an individual student responds to a question before the entire class without much time to think about his/her answer; such a situation creates a threatening environment.

6.2.9 Difficulties with the philosophy of group work

A problem in implementing collaborative learning arises because students lack an understanding of the underlying philosophies of collaborative learning. Our current system of mathematics education encourages competition and individual responsibility and discourages student interaction. Understandably, student resentment arises when they are asked to share information and study techniques or to help their peers.

[Quote from student]: I’m not quite happy the way things are because it’s not what I’m used to and I’m not comfortable in the way it’s now done. What I’m accustomed to is the teacher in the front of the class writing it on the board... and then set homework... So my learning is fairly teacher centred.

The higher ability students on the other hand have managed to get over this transition phase and learn how to be cooperative instead of always being competitive.
CHAPTER SIX: STUDY II - ATTITUDES TOWARDS GROUP WORK

[Quote from student]: It’s all the same subject, but in university... it’s taught in a different manner I suppose completely... I’m fine with it now, just means you’ve got to put more effort in than just sitting there.

Collaborative learning redefines the role of the student and the teacher and their interrelationships by creating a nurturing environment versus a competitive one.

• Less outspoken people in groups and unprepared students

Students with a quiet nature may not feel comfortable expressing themselves and their ideas with a group. These students that never talk might still not feel comfortable talking to a group. They would feel comfortable talking to a teacher one-to-one. It can be said that this could still be a good thing because the student that is afraid to talk will have more of a chance to talk in the group. Some students are shy or reserved and feel awkward when working with others. Forgetting about a particular group member can easily happen and therefore when students work in groups they should do their best to make sure everyone is involved. It is very easy for a student to just stay in the background and never really contribute anything to the group and thus learn nothing. For this reason, these students may feel more comfortable working alone than in a group.

Usually when forming groups, friends quickly get together and begin talking, using the class as a social hour. The shy, timid students, however, dread having to find a group of they can join. Slowly, these students may get together in an uncomfortable and quiet group.

[Quote from student]: If I don’t understand it... I feel a bit intimidated to say ‘Hey, can you explain that to me’. The only time that I feel that it's beneficial or whatever is when the whole group doesn’t understand so we put up our hand, the tutor comes over and explains it and then usually, the majority of us get it and that’s OK.

Some members in a group consider having quieter students in a group to be disadvantageous in terms of not contributing to the task at hand, as one student pointed out:
[Quote from student]: I do my best to contribute... the quieter people whether they know it or not sometimes just don't do anything.

There are also instances where members in a group do not come prepared for the tasks and other members in the group feel that this is a hindrance towards working cooperatively and collaboratively to complete the tasks that have been assigned:

[Quote from student]: In groups you have to be committed to your group and you have to be prepared before you come to the tutorial, but then some of the group members from my group - they just came, show up, so most of the time we get low marks and like nobody seems to care you know, so it's a little bit of a worry because you're not in the same level with the others, you know you want to put in effort, but then some of them they just came so it's a bit difficult.

6.2.10 Assessment issues

- **Unequal workload and assessment**

If one group member does not contribute as much as the others, then this will often leave the other members frustrated and the student who is not contributing will not really learn anything. Other members need to recognise that the non-contributing student needs to add more to the group. When students are placed into groups, many of the hard-working students do all of the work and the lazy or shy students do nothing and still receive the same grade. Not everyone in the group will participate and some students rely on others to do the work for them. These students usually receive the same grade, which is not fair to the students in the group who did all of the work, as one student pointed out:

[Quote from student]: I think well, I can imagine that you know some of us sit down and do it and someone doesn't and they're like... put my name on it’ or something and that does get a bit annoying because they don't contribute and so that's one thing that one negative aspect of group work -- the ones that don't contribute kind of get the marks or not the marks you really want to get.

It is important to note however, that this is only true if that is how the assessment is structured.
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The other side of the coin is when one member in the group is the only one that is 'able' to do the work and the rest just sit back and watch. It can be very frustrating if this one student realises that he/she is doing all the work:

[Quote from student]: ...it's not fair - like one boy sitting there can do all the questions and three other boys can watch or girls you know and I don't think that unless you have teacher that can monitor questions and all kids putting their name down on what they did - it's not fair - it's good for students like me who possibly aren't as gifted at maths as others because it pulls our marks up whereas say student X for instance, his marks will be pulled down because he'll be relying on myself and student Y to do questions whereas he only can do two questions in a set amount of time and if we did the other two and we don't get as high a mark as he would, we're sort of pulling him down so in a way it's sort of striking up an equilibrium between gifted and not so gifted students.

[Quote from student]: Hey, it's great because I've been riding on the back of intelligent people. I'd be really annoyed if I was in a group that didn't have as intelligent people because not only would I get frustrated with things I couldn't do, and the fact that nobody else could do them so not only would we do badly but I have no possibility of having someone in my group explain it to me, so the assessment for me at the moment is really advantageous but I can see how it can be really bad if the tables had turned certainly.

There were also some positive feedback about the assessment of group work and included comments like:

[Quote from student]: Group-based assessments - I think they're good. I think it's a fair way of assessing people in groups.

[Quote from student]: That's a good way of doing it I believe, like especially participation is important because otherwise you're going to have someone bludging, there's always someone who's going to not do something, it's the way of life but [laugh] umm I think it works well what they're doing, it's a decent assessment.
6.2.11 Fear of loss of content and ability to achieve high grades (Panitz, & Panitz, 1996)

Students initially do not have a clear way of knowing if the work they are doing is correct. The process of student-centred discovery and construction of their own knowledge base is new to most mathematics students. It is exactly this process that helps students develop critical thinking skills but they often resent the fact that group work shifts the burden of learning to themselves. Many feel much more comfortable hearing the teacher present the important facts instead of having to sort out what is important. A common fear among students is that all the group members will be wrong, leading to failure.

[Quote from student]: I don’t particularly like it - it’s just go in there and get in groups and work at the question, there’s no actual...learning and feedback from the tutors... we just basing our knowledge on what we have ourselves and other books provided and not actually getting any like guidance towards what... so a lot of time is wasted searching through materials...

The collaborative learning process calls for constant review and summary through whole class discussions and presentation of material by individuals and groups. In addition, the teacher is continuously observing the groups and making suggestions about how to proceed or where to go to find necessary information. Gradually, students become more comfortable with the process as they understand that their questions will be answered and that the teacher is an active participant in the process, taking on the role of facilitator or coach instead of expert information presenter.

6.3 Part II: Objectives of setting group work

Lecturers and course coordinators have certain objectives in mind in setting group work. Some of these objectives are listed below. A questionnaire was administered to students to determine how relevant they considered the objectives to be to their educational needs. Students responded to 10 items that asked about different reasons for setting group work by ticking the number on a three-point scale (where "1= Not at all relevant"; "2 = Fairly relevant"; and "3= Extremely relevant") that best reflected their
perceptions (see Table 6.1 below and Appendix A5 for questionnaire items). The questionnaire items were used from Zariski and Davis’ (1997) survey of student group work. Only item 19 (from a total of 39 questionnaire items) from their survey was used, which was administered to law students who had experienced some form of group work in their law studies. Their research was designed to reveal whether students understood and accepted the purposes lecturers had in mind in setting group work, whether those purposes were achieved, and how group work affected students’ academic lives. Therefore, I wanted to investigate what mathematics students considered to be the objectives for setting group work.

Table 6.1: Questionnaire items for objectives for setting group work

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To encourage an attitude of cooperation as opposed to competition</td>
</tr>
<tr>
<td>2</td>
<td>To encourage notions of trust and reliance on other students</td>
</tr>
<tr>
<td>3</td>
<td>To develop skills in organising and coordinating tasks and outcomes</td>
</tr>
<tr>
<td>4</td>
<td>To provide opportunities to teach and learn from other students</td>
</tr>
<tr>
<td>5</td>
<td>To stimulate student responsibility for their own learning</td>
</tr>
<tr>
<td>6</td>
<td>To encourage students to respect and value other students</td>
</tr>
<tr>
<td>7</td>
<td>To develop conflict resolution skills</td>
</tr>
<tr>
<td>8</td>
<td>To enhance in students the motivation to learn</td>
</tr>
<tr>
<td>9</td>
<td>To stimulate thought about the course content</td>
</tr>
<tr>
<td>10</td>
<td>To increase understanding of the course content</td>
</tr>
</tbody>
</table>

Questionnaire items 1, 2, 3, 4, 6, and 7 were grouped as dimension 1, which is labelled as **skills-based objectives**, while questionnaire items 5, 8, 9, and 10 were grouped as dimension 2, which is labelled as **conceptual-based objectives**. A principal component factor analysis with varimax rotation of the 10 items generated 2 constructs or factors, namely, **skills-based** and **conceptual-based**. This two-factor model accounted for 48% of the item variation (adjusted $R^2 = 47.566$). In other words, students perceived that objectives for setting group work accounted for just under half of the variance in gains. Figure 6.1 shows the scree plot of the two factors obtained from the factor analysis and Table 6.2 outlines the questionnaire items, this time sorted by the two constructs.
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obtained from the factor analysis. Table 6.3 displays the principal component analysis output, while Table 6.4 displays the rotated component matrix for the two factors.

Table 6.2: Questionnaire items sorted according to the two dimensions

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To encourage an attitude of cooperation as opposed to competition</td>
</tr>
<tr>
<td>2</td>
<td>To encourage notions of trust and reliance on other students</td>
</tr>
<tr>
<td>3</td>
<td>To develop skills in organising and coordinating tasks and outcomes</td>
</tr>
<tr>
<td>4</td>
<td>To provide opportunities to teach and learn from other students</td>
</tr>
<tr>
<td>5</td>
<td>To encourage students to respect and value other students</td>
</tr>
<tr>
<td>6</td>
<td>To develop conflict resolution skills</td>
</tr>
<tr>
<td>7</td>
<td>To stimulate student responsibility for their own learning</td>
</tr>
<tr>
<td>8</td>
<td>To enhance in students the motivation to learn</td>
</tr>
<tr>
<td>9</td>
<td>To stimulate thought about the course content</td>
</tr>
<tr>
<td>10</td>
<td>To increase understanding of the course content</td>
</tr>
</tbody>
</table>

Table 6.3: Principal component factor analysis for objectives of group work

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction Sums of Squared Loadings</th>
<th>Rotation Sums of Squared Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of Variance</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>2</td>
<td>1.186</td>
<td>11.858</td>
<td>47.565</td>
</tr>
<tr>
<td>4</td>
<td>.797</td>
<td>7.974</td>
<td>65.512</td>
</tr>
<tr>
<td>5</td>
<td>.719</td>
<td>7.187</td>
<td>72.700</td>
</tr>
<tr>
<td>6</td>
<td>.703</td>
<td>7.032</td>
<td>79.732</td>
</tr>
<tr>
<td>7</td>
<td>.603</td>
<td>6.029</td>
<td>85.760</td>
</tr>
<tr>
<td>8</td>
<td>.523</td>
<td>5.227</td>
<td>90.988</td>
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<tr>
<td>9</td>
<td>.482</td>
<td>4.824</td>
<td>95.812</td>
</tr>
<tr>
<td>10</td>
<td>.419</td>
<td>4.188</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Figure 6.1: Scree plot

Table 6.4: Rotated component matrix of the two factors

<table>
<thead>
<tr>
<th>Rotated Component Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
<td>Q10</td>
</tr>
<tr>
<td>Q9</td>
</tr>
<tr>
<td>Q8</td>
</tr>
<tr>
<td>Q5</td>
</tr>
<tr>
<td>Q1</td>
</tr>
<tr>
<td>Q2</td>
</tr>
<tr>
<td>Q6</td>
</tr>
<tr>
<td>Q4</td>
</tr>
<tr>
<td>Q3</td>
</tr>
<tr>
<td>Q7</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Figures 6.2a-f and 6.3a-d are histogram plots for the scores of each of the ten questionnaire items respectively. Figures 6.4 and 6.5 are histogram plots of the average scores for the two dimensions (or factors) obtained from the factor analysis respectively. *Skills-based* represents the mean score for dimension/factor I (namely, skills-based objectives) for each student, while *conceptual-based* represents the mean score for
dimension/factor 2 (namely, learning-based objectives). There was no difference in the average score for each of the two factors, with the average score for skills-based being 2.36 and the average score for conceptual-based being 2.40. Figures 6.6, 6.7, 6.8 and 6.9 are scatter plots of skills-based (average score of the 6 items in dimension 1) versus conceptual-based (average score of the 4 items in dimension 2) respectively plotted by age, gender, number of years spent in Australia and language spoken at home.

Figure 6.2a-f: Histogram plots of scores for questionnaire items regarding skills-based objectives.
Figure 6.3a-d: Histogram plots of scores for questionnaire items regarding conceptual-based objectives.

Figure 6.4: Histogram of average scores for skills-based objectives.
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Figure 6.5: Histogram of average scores for conceptual-based objectives.

Figure 6.6: Scatter plot of skills-based versus conceptual-based objectives by age.
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Figure 6.7: Scatter plot of *skills-based* versus *conceptual-based* objectives by sex.

Figure 6.8: Scatter plot of *skills-based* versus *conceptual-based* objectives by number of years in Australia.
Each of the four scatter plots of skills-based versus conceptual-based objectives by language spoken at home.

Figure 6.9: Scatter plot of skills-based versus conceptual-based objectives by language spoken at home.

Here is the caption and paragraph:

Each of the four scatter plots of skills-based versus conceptual-based above show a fairly positive relationship, which is not a desirable result since we were trying for independent dimensions. Next, a multivariate test using the general linear model was performed using the regression factor scores for skills-based and conceptual-based dimensions as dependent variables and age, sex, number of years, and language spoken as fixed factors (see Table 6.5 for output). There was no significant difference in the means (means ranging from 2.3 to 2.5) for either of the two dimensions across the four demographic variables tested (see Tables 6.6a-b and 6.7a-b). It can be inferred therefore that students regarded both skills-based objectives and conceptual-based objectives as equally important.
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Table 6.5: Multivariate test for skills-based and conceptual-based objectives using age, sex, number of years and language spoken as fixed factors

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>.216a</td>
<td>2.000</td>
<td>316.000</td>
<td>.806</td>
</tr>
<tr>
<td>Wilks' Lambda</td>
<td>.999</td>
<td>.216a</td>
<td>2.000</td>
<td>316.000</td>
<td>.806</td>
</tr>
<tr>
<td>Hotelling's Trace</td>
<td>.001</td>
<td>.216a</td>
<td>2.000</td>
<td>316.000</td>
<td>.806</td>
</tr>
<tr>
<td>Roy's Largest Root</td>
<td>.001</td>
<td>.216a</td>
<td>2.000</td>
<td>316.000</td>
<td>.806</td>
</tr>
<tr>
<td>AGE Pillai's Trace</td>
<td>.003</td>
<td>.446a</td>
<td>2.000</td>
<td>316.000</td>
<td>.640</td>
</tr>
<tr>
<td>Wilks' Lambda</td>
<td>.997</td>
<td>.446a</td>
<td>2.000</td>
<td>316.000</td>
<td>.640</td>
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<tr>
<td>Hotelling's Trace</td>
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<td>.446a</td>
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<td>316.000</td>
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</tr>
<tr>
<td>Roy's Largest Root</td>
<td>.003</td>
<td>.446a</td>
<td>2.000</td>
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<td>.640</td>
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<tr>
<td>SEX Pillai's Trace</td>
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<td>1.609b</td>
<td>2.000</td>
<td>316.000</td>
<td>.202</td>
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<tr>
<td>Wilks' Lambda</td>
<td>.990</td>
<td>1.609b</td>
<td>2.000</td>
<td>316.000</td>
<td>.202</td>
</tr>
<tr>
<td>Hotelling's Trace</td>
<td>.010</td>
<td>1.609b</td>
<td>2.000</td>
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<td>.202</td>
</tr>
<tr>
<td>Roy's Largest Root</td>
<td>.010</td>
<td>1.609b</td>
<td>2.000</td>
<td>316.000</td>
<td>.202</td>
</tr>
<tr>
<td>YEARS Pillai's Trace</td>
<td>.001</td>
<td>.151a</td>
<td>2.000</td>
<td>316.000</td>
<td>.860</td>
</tr>
<tr>
<td>Wilks' Lambda</td>
<td>.999</td>
<td>.151a</td>
<td>2.000</td>
<td>316.000</td>
<td>.860</td>
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<tr>
<td>Hotelling's Trace</td>
<td>.001</td>
<td>.151a</td>
<td>2.000</td>
<td>316.000</td>
<td>.860</td>
</tr>
<tr>
<td>Roy's Largest Root</td>
<td>.001</td>
<td>.151a</td>
<td>2.000</td>
<td>316.000</td>
<td>.860</td>
</tr>
<tr>
<td>LANGUAGE Pillai's Trace</td>
<td>.011</td>
<td>.602</td>
<td>6.000</td>
<td>634.000</td>
<td>.729</td>
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<tr>
<td>Wilks' Lambda</td>
<td>.989</td>
<td>.601a</td>
<td>6.000</td>
<td>632.000</td>
<td>.730</td>
</tr>
<tr>
<td>Hotelling's Trace</td>
<td>.011</td>
<td>.599</td>
<td>6.000</td>
<td>630.000</td>
<td>.731</td>
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<tr>
<td>Roy's Largest Root</td>
<td>.008</td>
<td>.812b</td>
<td>3.000</td>
<td>317.000</td>
<td>.488</td>
</tr>
</tbody>
</table>

a. Exact statistic
b. The statistic is an upper bound on F that yields a lower bound on the significance level.
c. Design: Intercept+AGE+SEX+YEARS+LANGUAGE

Table 6.6a-b: Estimated marginal means for skills-based and conceptual-based objectives by age, and sex respectively

1. AGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>AGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>high school students</td>
<td>2.366</td>
<td>.047</td>
<td>2.273 - 2.458</td>
</tr>
<tr>
<td>SKILLS</td>
<td>mature age students</td>
<td>2.410</td>
<td>.060</td>
<td>2.292 - 2.528</td>
</tr>
<tr>
<td></td>
<td>high school students</td>
<td>2.367</td>
<td>.059</td>
<td>2.249 - 2.484</td>
</tr>
<tr>
<td>CONCEPT</td>
<td>mature age students</td>
<td>2.416</td>
<td>.076</td>
<td>2.267 - 2.565</td>
</tr>
</tbody>
</table>

2. SEX

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>SEX</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>male</td>
<td>2.346</td>
<td>.035</td>
<td>2.277 - 2.416</td>
</tr>
<tr>
<td>SKILLS</td>
<td>female</td>
<td>2.429</td>
<td>.073</td>
<td>2.286 - 2.573</td>
</tr>
<tr>
<td></td>
<td>male</td>
<td>2.421</td>
<td>.045</td>
<td>2.333 - 2.509</td>
</tr>
<tr>
<td>CONCEPT</td>
<td>female</td>
<td>2.361</td>
<td>.092</td>
<td>2.180 - 2.542</td>
</tr>
</tbody>
</table>
### CHAPTER SIX: STUDY II - ATTITUDES TOWARDS GROUP WORK

Table 6.7a-b: Estimated marginal means for skills-based and conceptual-based objectives by number of years and language spoken respectively

#### 3. YEARS

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>YEARS</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>SKILLS</td>
<td>recent immigrants</td>
<td>2.375</td>
<td>.062</td>
<td>2.252</td>
</tr>
<tr>
<td></td>
<td>Australian residents</td>
<td>2.401</td>
<td>.046</td>
<td>2.310</td>
</tr>
<tr>
<td>CONCEPT</td>
<td>recent immigrants</td>
<td>2.371</td>
<td>.079</td>
<td>2.216</td>
</tr>
<tr>
<td></td>
<td>Australian residents</td>
<td>2.412</td>
<td>.058</td>
<td>2.297</td>
</tr>
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</table>

#### 4. LANGUAGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LANGUAGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>SKILLS</td>
<td>English speakers</td>
<td>2.374</td>
<td>.055</td>
<td>2.267</td>
</tr>
<tr>
<td></td>
<td>Middle Eastern</td>
<td>2.416</td>
<td>.081</td>
<td>2.256</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>2.410</td>
<td>.044</td>
<td>2.324</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>2.351</td>
<td>.078</td>
<td>2.196</td>
</tr>
<tr>
<td>CONCEPT</td>
<td>English speakers</td>
<td>2.368</td>
<td>.069</td>
<td>2.232</td>
</tr>
<tr>
<td></td>
<td>Middle Eastern</td>
<td>2.476</td>
<td>.103</td>
<td>2.274</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>2.368</td>
<td>.056</td>
<td>2.259</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>2.352</td>
<td>.099</td>
<td>2.157</td>
</tr>
</tbody>
</table>

Table 6.8a-b: Estimated marginal means for skills-based and conceptual-based objectives by age and sex respectively.

#### 1. AGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>AGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>REGR factor score</td>
<td>high school</td>
<td>-8.55E-02</td>
<td>.122</td>
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</tr>
<tr>
<td>1 for analysis 2</td>
<td>mature age</td>
<td>5.056E-02</td>
<td>.156</td>
<td>-.256</td>
</tr>
<tr>
<td></td>
<td>students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REGR factor score</td>
<td>high school</td>
<td>5.356E-02</td>
<td>.122</td>
<td>-.186</td>
</tr>
<tr>
<td>2 for analysis 2</td>
<td>mature age</td>
<td>9.723E-02</td>
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<td>-.208</td>
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<tr>
<td></td>
<td>students</td>
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<td></td>
</tr>
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</table>

#### 2. SEX

<table>
<thead>
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<th>Dependent Variable</th>
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<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>REGR factor score</td>
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<td>-.108</td>
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<tr>
<td>1 for analysis 2</td>
<td>female</td>
<td>-.107</td>
<td>.189</td>
<td>-.479</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REGR factor score</td>
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<td>-5.92E-02</td>
<td>.092</td>
<td>-.239</td>
</tr>
<tr>
<td>2 for analysis 2</td>
<td>female</td>
<td>.210</td>
<td>.188</td>
<td>-.161</td>
</tr>
</tbody>
</table>
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Table 6.9a-b: Estimated marginal means for skills-based and conceptual-based objectives by number of years and language spoken respectively

3. YEARS

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>YEARS</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>REGR factor score</td>
<td>recent immigrants</td>
<td>-.92E-02</td>
<td>.162</td>
<td>-.377</td>
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<tr>
<td>1 for analysis 2</td>
<td>Australian residents</td>
<td>2.43E-02</td>
<td>.120</td>
<td>-.212</td>
</tr>
<tr>
<td></td>
<td>recent immigrants</td>
<td>6.20E-02</td>
<td>.161</td>
<td>-.255</td>
</tr>
<tr>
<td>2 for analysis 2</td>
<td>Australian residents</td>
<td>8.87E-02</td>
<td>.120</td>
<td>-.147</td>
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</table>

4. LANGUAGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LANGUAGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>REGR factor score</td>
<td>English speakers</td>
<td>-4.45E-02</td>
<td>.142</td>
<td>-.324</td>
</tr>
<tr>
<td>1 for analysis 2</td>
<td>Middle Eastern</td>
<td>.165</td>
<td>.211</td>
<td>-.250</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>-.113</td>
<td>.114</td>
<td>-.338</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>-7.73E-02</td>
<td>.204</td>
<td>-.478</td>
</tr>
<tr>
<td></td>
<td>English speakers</td>
<td>3.11E-02</td>
<td>.142</td>
<td>-.248</td>
</tr>
<tr>
<td>2 for analysis 2</td>
<td>Middle Eastern</td>
<td>9.80E-02</td>
<td>.210</td>
<td>-.316</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>.182</td>
<td>.114</td>
<td>-.4.23E-02</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>-9.83E-03</td>
<td>.203</td>
<td>-.409</td>
</tr>
</tbody>
</table>

In reference to the definition of the two dimensions, I used an actual combination of questions as defined by the factor analysis and histogram plots as well as scatter plots of the new scores, namely reg_ski! (regression factor scores for skill based objectives) and reg_conc (regression factor scores for concept based objectives) with markers set by age, sex, number of years and language spoken were plotted (see figures 6.10 and 6.11 for the histogram plots and figures 6.12, 6.13, 6.14 and 6.15 for the scatter plots). This time the two dimensions produce a graph that is much more like two independent variables should be.
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Regression factor score for skills-based objectives

Figure 6.10: Histogram of the regression factor scores for the skills-based dimension.

Regression factor score for concept-based objectives

Figure 6.11: Histogram of the regression factor scores for the conceptual-based dimension.
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Figure 6.12: Scatter plot of regression factor scores of *skills-based* versus *conceptual-based* objectives with markers set by age.

Figure 6.13: Scatter plot of regression factor scores of *skills-based* versus *conceptual-based* objectives with markers set by sex.
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Figure 6.14: Scatter plot of regression factor scores of skills-based versus conceptual-based objectives with markers set by number of years in Australia.

Figure 6.15: Scatter plot of regression factor scores of skills-based versus conceptual-based objectives with markers set by language spoken at home.
6.4 Discussion of findings concerning students' prioritisation of objectives for setting group work

Table 6.10 shows that both high-school leavers (54%) and mature age students (60%) place greater emphasis on skills-based objectives for setting group work. In addition, mature age students placed a greater emphasis than did the high-school leavers, which indicates that mature age students are more conscious about the usefulness of group work in building up skills for current or later use in the workforce.

Both male and female students regarded skills-based objectives as being more important or relevant compared with learning-based objectives. In particular, a clear majority of female students felt this way (63%) compared with just 37% indicating learning-based skills as important objectives (see Table 6.11). Male students, on the other hand, did not have strong preferences for either skills-based or conceptual-based objectives and viewed them as both being important objectives for setting group based tasks. A numerical comparison was done between the skills-based and conceptual-based objectives' scores and the results are displayed in the tables below.

Table 6.10: Data summary statistics by age

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>%</th>
<th>skills-based &gt; conceptual-based</th>
<th>conceptual-based &gt; skills-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-school leavers (1)</td>
<td>269</td>
<td>88</td>
<td>146</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mature-age students (2)</td>
<td>65</td>
<td>11</td>
<td>39</td>
<td>60</td>
</tr>
</tbody>
</table>

\[ Data summary for the number of instances where the score for skills-based objectives was higher than the score for conceptual-based objectives.

\[ Data summary for the number instances where the score for conceptual-based objectives was higher than the score for skills-based objectives.\]
CHAPTER SIX: STUDY JI-ATTITUDES TOWARDS GROUP WORK

Table 6.11: Data summary statistics by sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>N</th>
<th>%</th>
<th>skills-based &gt; conceptual-based</th>
<th>conceptual-based &gt; skills-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Male (1)</td>
<td>304</td>
<td>78</td>
<td>160</td>
<td>53</td>
</tr>
<tr>
<td>Female (2)</td>
<td>38</td>
<td>19</td>
<td>24</td>
<td>63</td>
</tr>
</tbody>
</table>

In relation to the number of years students had spent in Australia (Table 6.12), both recent immigrants and students who had spent 6 years or more in Australia indicated a priority towards skills-based objectives for group work (57% and 53% respectively), but it was stronger in the case of recent migrants than of Australian residents. This indicates that the students who had been in the country for a considerable number of years place an almost equal emphasis on both skills-based and learning-based objectives.

Table 6.12: Data summary statistics by number of years in Australia

<table>
<thead>
<tr>
<th>Number of Years</th>
<th>N</th>
<th>%</th>
<th>skills-based &gt; conceptual-based</th>
<th>conceptual-based &gt; skills-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Recent Immigrants (1)</td>
<td>61</td>
<td>18</td>
<td>35</td>
<td>57</td>
</tr>
<tr>
<td>Australian Residents (2)</td>
<td>277</td>
<td>81</td>
<td>147</td>
<td>53</td>
</tr>
</tbody>
</table>

Table 6.13: Data summary statistics by language spoken at home

<table>
<thead>
<tr>
<th>Language Spoken</th>
<th>N</th>
<th>%</th>
<th>skills-based &gt; conceptual-based</th>
<th>conceptual-based &gt; skills-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>English (1)</td>
<td>131</td>
<td>38</td>
<td>66</td>
<td>50</td>
</tr>
<tr>
<td>Middle Eastern (2)</td>
<td>32</td>
<td>9</td>
<td>14</td>
<td>44</td>
</tr>
<tr>
<td>Asian (3)</td>
<td>146</td>
<td>42</td>
<td>86</td>
<td>59</td>
</tr>
<tr>
<td>European (4)</td>
<td>32</td>
<td>9</td>
<td>17</td>
<td>53</td>
</tr>
</tbody>
</table>
Finally, in relation to students' cultural background and language spoken at home, the results were quite interesting (see Table 6.13). There was absolutely no difference among English speakers in relation to how they prioritise the objectives for group work. Only 41% of students from an Asian and Indian background indicated learning-based objectives as being important, compared with 59% indicating skills-based objectives as a priority. European students were of almost equal opinion, which can be taken to mean that they considered both skill-based and learning-based objectives as equally important. Students from a Middle Eastern background were in a different pool with a greater proportion of them indicating learning-based objectives as a priority (56%) as opposed to only 44% considering skills-based objectives as important.

So, what we see from this is that all students that were surveyed placed a greater emphasis on skills-based objectives for setting group work as opposed to conceptual-based objectives. The only cohort that indicated otherwise was the group of Middle Eastern students which was interesting. What this means is that students value the development of skills such as cooperation, trust, reliance, organisation, respect, and conflict resolution as important not only in a study environment but perhaps also in the workplace.

6.5 Synopsis of chapter

This chapter has looked at the data on students' views about group work and what they consider to be the objectives for setting group work in mathematics. The effects of age, gender, language background and length of stay in Australia have been investigated. The results were obtained from both a qualitative and quantitative study. The results obtained from both were interesting in certain regards. The student quotes that supplemented literature indicated that collaborative learning has an overall positive effect in the cognitive domain as well as the social and affective domain in tertiary mathematics.

The mean scores were not statistically significant with the average score for the skills-based objectives being 2.4 and the average score for the conceptual-based objectives being 2.4 as well. The scatter plots of the two dimensions plotted against each other with markers set by each of the four variables of interest displayed a positive
relationship. The multivariate analysis of variance (MANOVA) produced no statistically significant results for any of the four variables - age, sex, length of stay in Australia and language spoken at home. The marginal means for the two dimensions across the four demographic variables were not statistically different. This indicates that was no difference in what male or female students; high-school leavers or mature age students; recent immigrants or Australian residents; Native and non-Native English speaking students considered to be the objectives for setting group work. In other words, they considered the objectives to all be equally important and relevant.

A different analysis was also done in regard to the number of instances where the mean score for the skills-based dimension was greater (or less) than the mean score for the conceptual-based dimension. The results were tabulated in Tables 6.9-6.12 and sorted by the four variables of interest. Zariski and Davis (1997) asked their students which were the three most relevant objectives to them and they chose cooperation (item 1), conflict resolution skills (item 7) and organising skills (item 3). All these three objectives fall under the skills-based objectives dimension. This question was not put to students in my study but the results from the analysis done in section 6.4 are nevertheless interesting.

The analysis showed that there were no statistically significant difference across the two age groups or between recent immigrants and Australian residents. However, looking at gender, of the 38 female students in the sample, 63% indicated skills-based objectives as being more relevant to them than the conceptual-based objectives. Male students appeared to place equal importance on both types of objectives.

Looking at language/cultural diversity, the results were not statistically significant (if compared with the MANOVA results), but it is interesting to note that in the Asian and Middle Eastern language groups we find a disparity in opinion. 56% of the Middle Eastern students (n = 32) considered conceptual-based objectives to be more important and relevant while 59% of the Asian students (n = 146) considered skills-based objectives to be more important and relevant.
In summary, the findings from this study are listed below:

a. Mature students placed a greater emphasis on skills-based objectives.

b. A greater proportion of female students regarded skills-based objectives as important.

c. Recent immigrants to Australia placed a greater emphasis on skills-based objectives.

d. Students of Middle-Eastern descent were the only group which indicated that conceptual-based objectives were more important than skills-based objectives.

There is no doubt that implementing collaborative learning is a structured but complex process. The reasons and aims for setting group work need to be properly explained to students prior to administering the group work so that students clearly understand the objectives behind setting collaborative activities. It must be noted that much of the research on collaborative learning has proposed that the benefits are usually long term rather than having an instant effect. Examination marks may not increase immediately but using properly structured group work early in a degree course can help the students to reflect more on their work. This can only be of benefit in later subjects that build upon the foundation courses.

Changes in teaching and learning styles are not a quick and easy matter. Change is a gradual process that involves both trying out new strategies and techniques as well as carefully considering the goals for which those practices are intended. Instructors are currently faced with a variety of challenges like large class size, diverse student populations, management problems, accountability pressures, legal issues, curriculum changes and new technology as well as age, cultural and language diversity. The use of collaborative learning strategies in mathematics can make classroom life for instructors and students more supportive, appealing, engaging, intellectually stimulating, creative, interesting, mathematically productive and fun.
Chapter 7

Study Three: Students' perceptions of using computer algebra systems in the learning of mathematics: Results and analysis of findings

7.1 Introduction

Educators are working towards changing the content of the mathematics curriculum and the ways in which it is taught in order to best prepare students for the 'real world', by moving from a focus on arithmetic and computational skills toward a curriculum that develops students' abilities to think, reason, and communicate mathematically (Petocz & Reid, 2005; Burton, 2004). The goal is to help students construct their conceptual understanding of mathematics, not just memorise facts and rules.

The teaching of mathematics is likewise changing in order to meet these new goals. Instead of teaching by telling or by demonstration, a blend of instructional methodologies is being used that includes individual and group work and direct instruction. The focus is to provide frequent opportunities for students to explore and solve problems, individually and with others; and to develop their mathematical skills in the context of this exploration. The lecturer becomes facilitator of learning, guiding
students' explorations, asking questions that extend their thinking, and encouraging students to communicate their thinking. One of the catalysts for change is the widespread and increasing use of computer algebra systems by professional mathematicians and in teaching and learning mathematics.

7.2 The study

It should be noted that this study deals with a much wider issue rather than being the focus of the thesis investigation. Three hundred and forty four participants (first-year engineering students studying a core mathematics subject) from a cohort of about 380 took part in the study. They worked on collaborative group activities during their set tutorials times and computer laboratory classes for one semester. Participants were evaluated on the work they produced during the tutorials and laboratory sessions. Students completed a questionnaire on their learning style preferences (see study I in chapter five). The questionnaire also sought additional information regarding students' attitudes towards using computers, attitudes towards group-based assessment, and their reactions towards group work in mathematics. Twenty students were interviewed in depth about their attitudes. Interviews were audio-taped and transcribed.

During the laboratory sessions, students sat in pairs – two to a computer - so that they could collaborate on the task at hand and use the software Mathematica to solve the problems. The results and discussion of findings from the questionnaire concerning students' attitudes towards using computers in learning mathematics are presented here and have been published in D'Souza et al., (2005). Several quotes from the interviews are used to illustrate the questionnaire data. The questionnaire items were adapted from Whitrow (1999). Not all the items in Whitrow's questionnaire were used in this study.

Whitrow (1999) looked at 154 year 8 students' attitudes towards computers at a metropolitan public school in Adelaide, South Australia following their participation in an integrated computer curriculum program. The findings of study indicated that there were no significant differences between males and females students' prior computer use. There was a significant change in students' behavioural component of attitude after participation in the integrated computer program, but not in their total attitude toward
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computers, nor in the affective, cognitive or perceived computer usefulness attitude components. The findings also indicated that there were no significant differences in students' changes in attitude with respect to gender, prior computer use or the combination thereof. Consequently, I wanted to use this questionnaire to determine if the effects were the same or different when looking at first-year undergraduate students.

The research questions being posed in this chapter are as follows:
1. What are tertiary students' attitudes towards the use of computer algebra systems in mathematics learning?
2. What impact do age, gender, number of years in Australia, and language spoken have on their attitudes toward using CAS?

7.3 Analysis and results

Students responded to 20 items by circling the number on a seven-point scale (where "1 = strongly disagree", "2 = disagree", "3 = mildly disagree", "4 = neutral", and "5 = mildly agree", "6 = agree", "7 = strongly agree") that best reflected their perceptions (see Appendix A6 for questionnaire items).

The results were analysed using a principal components factor analysis with varimax rotation, leading to a two-factor model accounting for 42% of the total variance (no other factor accounted for more than 7.5%). Each factor summarises an independent dimension in the data. Factor 1 was named 'Anxiety': Students displaying computer anxiety and who see computers as an interference tool (based largely on items 1, 2, 9, 10, 12, 15 and 19, as well as 7, 11 and 13 negatively scored). Factor 2 was named 'Benefits': Computers viewed as a tool for understanding concepts and used with positive self-confidence (based largely on items 4, 5, 6, 8, 14, 16, 17, and 20). Items 3 and 18 did not contribute significantly to either dimension.
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Table 7.1: Factor analysis output of the questionnaire items

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction Sums of Squared Loadings</th>
<th>Rotation Sums of Squared Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of Variance</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>1</td>
<td>6.426</td>
<td>32.130</td>
<td>32.130</td>
</tr>
<tr>
<td>2</td>
<td>2.049</td>
<td>10.246</td>
<td>42.375</td>
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<tr>
<td>3</td>
<td>1.449</td>
<td>7.246</td>
<td>49.621</td>
</tr>
<tr>
<td>4</td>
<td>1.252</td>
<td>6.259</td>
<td>55.880</td>
</tr>
<tr>
<td>5</td>
<td>1.046</td>
<td>5.229</td>
<td>61.109</td>
</tr>
<tr>
<td>6</td>
<td>.883</td>
<td>4.417</td>
<td>65.526</td>
</tr>
<tr>
<td>7</td>
<td>.800</td>
<td>3.998</td>
<td>69.524</td>
</tr>
<tr>
<td>8</td>
<td>.722</td>
<td>3.611</td>
<td>73.134</td>
</tr>
<tr>
<td>9</td>
<td>.687</td>
<td>3.433</td>
<td>76.568</td>
</tr>
<tr>
<td>10</td>
<td>.620</td>
<td>3.099</td>
<td>79.666</td>
</tr>
<tr>
<td>11</td>
<td>.579</td>
<td>2.896</td>
<td>82.562</td>
</tr>
<tr>
<td>12</td>
<td>.553</td>
<td>2.763</td>
<td>85.325</td>
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<td>13</td>
<td>.463</td>
<td>2.315</td>
<td>87.640</td>
</tr>
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<td>14</td>
<td>.442</td>
<td>2.210</td>
<td>89.850</td>
</tr>
<tr>
<td>15</td>
<td>.404</td>
<td>2.020</td>
<td>91.870</td>
</tr>
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<td>16</td>
<td>.373</td>
<td>1.864</td>
<td>93.734</td>
</tr>
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<td>17</td>
<td>.345</td>
<td>1.727</td>
<td>95.461</td>
</tr>
<tr>
<td>18</td>
<td>.323</td>
<td>1.617</td>
<td>97.078</td>
</tr>
<tr>
<td>19</td>
<td>.308</td>
<td>1.538</td>
<td>98.616</td>
</tr>
<tr>
<td>20</td>
<td>.277</td>
<td>1.384</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.

Figure 7.1: Scree plot of the two dimensions
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Table 7.2: Rotated component matrix

<table>
<thead>
<tr>
<th>Component Matrix a</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5</td>
<td>.742</td>
<td>-.337</td>
</tr>
<tr>
<td>Q16</td>
<td>.714</td>
<td>-.103</td>
</tr>
<tr>
<td>Q6</td>
<td>.713</td>
<td>-.362</td>
</tr>
<tr>
<td>Q17</td>
<td>.704</td>
<td>-.102</td>
</tr>
<tr>
<td>Q14</td>
<td>.667</td>
<td>-.108</td>
</tr>
<tr>
<td>Q8</td>
<td>.640</td>
<td>-.195</td>
</tr>
<tr>
<td>Q4</td>
<td>.617</td>
<td>-.314</td>
</tr>
<tr>
<td>Q20</td>
<td>.617</td>
<td>-.795E-02</td>
</tr>
<tr>
<td>Q9</td>
<td>8.025E-02</td>
<td>.761</td>
</tr>
<tr>
<td>Q10</td>
<td>-3.25E-02</td>
<td>.751</td>
</tr>
<tr>
<td>Q11</td>
<td>.151</td>
<td>-.715</td>
</tr>
<tr>
<td>Q7</td>
<td>.405</td>
<td>-.631</td>
</tr>
<tr>
<td>Q12</td>
<td>-.159</td>
<td>.614</td>
</tr>
<tr>
<td>Q13</td>
<td>.231</td>
<td>-.544</td>
</tr>
<tr>
<td>Q1</td>
<td>-.359</td>
<td>.520</td>
</tr>
<tr>
<td>Q2</td>
<td>-.182</td>
<td>.497</td>
</tr>
<tr>
<td>Q15</td>
<td>-.182</td>
<td>.466</td>
</tr>
<tr>
<td>Q19</td>
<td>-.185</td>
<td>.418</td>
</tr>
<tr>
<td>Q3</td>
<td>.271</td>
<td>-.297</td>
</tr>
<tr>
<td>Q18</td>
<td>-9.69E-02</td>
<td>253</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Figure 7.2: Histogram of dimension 1 (anxiety) scores
Figures 7.3, 7.4, 7.5, and 7.6 are scatter plots of anxiety (average score of the 10 items in dimension 1) versus benefits (average score of the 8 items in dimension 2) respectively with markers set by age, gender, number of years spent in Australia and language spoken at home respectively.

Figure 7.4: Scatter plot of anxiety versus benefits with markers set by age
CHAPTER SEVEN: STUDY IIJ - ATTITUDES TOWARDS USING CAS

Figure 7.5: Scatter plot of anxiety versus benefits with markers set by sex

Figure 7.6: Scatter plot of anxiety versus benefits with markers set by number of years in Australia
The plots above are a graphical way to show the relationship between the two factors (benefits and anxiety) and their interaction with the various demographic variables. A multivariate test using the general linear model was performed using anxiety and benefits as dependent variables and age, sex, number of years, and language spoken as fixed factors (see Table 7.3 for output).

Each of the four scatter plots of anxiety versus benefits above show a fairly strong negative relationship, which is not desirable since we were trying for independent dimensions. Take for instance the scatter plot for anxiety versus benefits with markers set by sex. The plot shows that female students are generally at the top right, which means that their appreciation of the benefits is higher but also their anxiety is higher. This is shown to be significant in a multivariate analysis ($p = 0.01$). These results are similar to those found in Galbraith and Haines (2000). Similarly, the effect of language background is significant ($p = 0.02$) as shown on the plot.
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The Asian language background students are about the same as English-speaking background students on benefits and higher on anxiety; European-language speaking students are lower on benefits and lower on anxiety. Middle Eastern language background students are lowest on benefits and by far the highest on anxiety. By examining the plots for age and number of years in Australia, we can see that there is no obvious pattern between the variables and that are only marginally significant differences between mature age students and school leavers \( (p = 0.06) \) and no significant differences between recent migrants and longer-term Australian residents \( (p = 0.30) \).

It is interesting to note that language background is significant but recent migrant status is not \( (p\text{-value} = 0.02 \text{ versus } 0.3) \). The recent migrants include international students. The fact that women display more computer anxiety is well known \( (\text{Galbraith} \& \text{Haines, 2000}) \), but it is surprising to find that this is still true for women who choose to study engineering. There is an ongoing need to support some female students and non-English speaking background students when introducing technology in order to reduce anxiety.

Table 7.3: Multivariate test for regression factors scores of anxiety and benefits using age, sex, number of years and language spoken as fixed factors

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillai’s Trace</th>
<th>Wilks’ Lambda</th>
<th>Hotelling’s Trace</th>
<th>Roy’s Largest Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.016</td>
<td>2.304*</td>
<td>2.000</td>
<td>289.000</td>
</tr>
<tr>
<td>AGE</td>
<td>0.019</td>
<td>2.832*</td>
<td>2.000</td>
<td>289.000</td>
</tr>
<tr>
<td>SEX</td>
<td>0.030</td>
<td>4.450*</td>
<td>2.000</td>
<td>289.000</td>
</tr>
<tr>
<td>YEARS</td>
<td>0.008</td>
<td>1.205*</td>
<td>2.000</td>
<td>289.000</td>
</tr>
<tr>
<td>LANGUAGE</td>
<td>0.053</td>
<td>2.631*</td>
<td>6.000</td>
<td>580.000</td>
</tr>
</tbody>
</table>

a. Exact statistic  
b. The statistic is an upper bound on F that yields a lower bound on the significance level.  
c. Design: Intercept+AGE+SEX+YEARS+LANGUAGE
CHAPTER SEVEN: STUDY III-ATTITUDES TOWARDS USING CAS

There was no significant difference in the means for either of the two dimensions across the two age groups, the two gender groups or even between recent immigrants and Australian residents (see Tables 7.4a-b, 7.4c-d and 7.5a-d). However, with respect to language spoken at home, results were interesting as indicated by the marginally significant p-value.

There was a 0.6 difference in the mean score of Middle Eastern students (mean = 3.8) and European students in the anxiety dimension, indicating that European students (mean = 3.2) had a marginally higher level of anxiety in relation to the use of computers. In the benefits dimension, there was a 0.9 difference in the mean score of English speakers (mean = 5.0) and Middle Eastern students (mean = 4.1), where in this case the former group indicated the positive aspects of using CAS in the learning of mathematics.

Table 7.4a-b: Estimated marginal means for anxiety and benefits by age and sex respectively

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>AGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>ANXIETY</td>
<td>high school students</td>
<td>3.652</td>
<td>.116</td>
<td>3.423</td>
</tr>
<tr>
<td></td>
<td>mature age students</td>
<td>3.404</td>
<td>.147</td>
<td>3.116</td>
</tr>
<tr>
<td>BENEFITS</td>
<td>high school students</td>
<td>4.709</td>
<td>.114</td>
<td>4.485</td>
</tr>
<tr>
<td></td>
<td>mature age students</td>
<td>4.622</td>
<td>.143</td>
<td>4.340</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>SEX</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>ANXIETY</td>
<td>male</td>
<td>3.448</td>
<td>.088</td>
<td>3.275</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>3.609</td>
<td>.178</td>
<td>3.260</td>
</tr>
<tr>
<td>BENEFITS</td>
<td>male</td>
<td>4.710</td>
<td>.086</td>
<td>4.541</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>4.620</td>
<td>.173</td>
<td>4.279</td>
</tr>
</tbody>
</table>
Table 7.4c-d: Estimated marginal means for *anxiety* and *benefits* by number of years and language spoken respectively

### 3. YEARS

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>YEARS</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANXIETY</td>
<td>recent immigrants</td>
<td>3.588</td>
<td>.152</td>
<td>3.289 - 3.888</td>
</tr>
<tr>
<td></td>
<td>Australian residents</td>
<td>3.469</td>
<td>.114</td>
<td>3.244 - 3.693</td>
</tr>
<tr>
<td>BENEFITS</td>
<td>recent immigrants</td>
<td>4.566</td>
<td>.149</td>
<td>4.273 - 4.858</td>
</tr>
<tr>
<td></td>
<td>Australian residents</td>
<td>4.765</td>
<td>.112</td>
<td>4.545 - 4.984</td>
</tr>
</tbody>
</table>

### 4. LANGUAGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LANGUAGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANXIETY</td>
<td>English speakers</td>
<td>3.408</td>
<td>.135</td>
<td>3.142 - 3.674</td>
</tr>
<tr>
<td></td>
<td>Middle Eastern</td>
<td>3.904</td>
<td>.199</td>
<td>3.513 - 4.295</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>3.480</td>
<td>.109</td>
<td>3.265 - 3.695</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>3.321</td>
<td>.196</td>
<td>2.936 - 3.707</td>
</tr>
<tr>
<td>BENEFITS</td>
<td>English speakers</td>
<td>4.895</td>
<td>.132</td>
<td>4.635 - 5.155</td>
</tr>
<tr>
<td></td>
<td>Middle Eastern</td>
<td>4.205</td>
<td>.194</td>
<td>3.823 - 4.587</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>4.797</td>
<td>.107</td>
<td>4.587 - 5.007</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>4.763</td>
<td>.191</td>
<td>4.386 - 5.140</td>
</tr>
</tbody>
</table>

In reference to the definition of the two dimensions, I used an actual combination of questions as defined by the factor analysis and histogram plots, as well as creating scatter plots of the new scores, i.e. regression factor scores for *anxiety* versus the regression factor scores for *benefits* with markers set by age, sex, number of years and language spoken (see Figures 7.7 and 7.8 for the histogram plots and Figures 7.9, 7.10, 7.11 and 7.12 for the scatter plots). This time the two dimensions produce a graph that is much more like two independent variables should be.
Table 7.5a-d: Estimated marginal means for regression factor scores of *anxiety* and *benefits* by age, sex, number of years and language spoken respectively

### 1. AGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>AGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>high school students</td>
<td>-.407E-02</td>
<td>.126</td>
<td>-.288 to .207</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>mature age students</td>
<td>-.289</td>
<td>.159</td>
<td>-.801 to 2.387E-02</td>
</tr>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>high school students</td>
<td>.335</td>
<td>.124</td>
<td>.028E-02 to .579</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>mature age students</td>
<td>6.369E-02</td>
<td>.157</td>
<td>-.245 to .372</td>
</tr>
</tbody>
</table>

### 2. SEX

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>SEX</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>male</td>
<td>-.285</td>
<td>.095</td>
<td>-.472 to .972E-02</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>female</td>
<td>-.446E-02</td>
<td>.191</td>
<td>-.620 to .331</td>
</tr>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>female</td>
<td>-.402E-02</td>
<td>.094</td>
<td>-.622 to .145</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>male</td>
<td>.439</td>
<td>.188</td>
<td>6.825E-02 to .809</td>
</tr>
</tbody>
</table>

### 3. YEARS

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>YEARS</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>recent immigrants</td>
<td>-.220</td>
<td>.165</td>
<td>-.545 to .105</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>Australian residents</td>
<td>-.109</td>
<td>.123</td>
<td>-.352 to .133</td>
</tr>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>recent immigrants</td>
<td>.315</td>
<td>.163</td>
<td>8.342E-02 to .636</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>Australian residents</td>
<td>8.342E-02</td>
<td>.121</td>
<td>-.156 to .323</td>
</tr>
</tbody>
</table>

### 4. LANGUAGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LANGUAGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>English speakers</td>
<td>2.625E-03</td>
<td>.147</td>
<td>-.286 to .292</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>Middle Eastern</td>
<td>-.468</td>
<td>.224</td>
<td>-.910 to -2.67E-02</td>
</tr>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>Asian &amp; Indian</td>
<td>6.398E-02</td>
<td>.117</td>
<td>-.166 to .294</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>European</td>
<td>-.257</td>
<td>.208</td>
<td>-.667 to .153</td>
</tr>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>English speakers</td>
<td>7.228E-02</td>
<td>.145</td>
<td>-.321 to .357</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>Middle Eastern</td>
<td>.577</td>
<td>.221</td>
<td>.142 to 1.01E-02</td>
</tr>
<tr>
<td>REGR factor score 1 for analysis</td>
<td>Asian &amp; Indian</td>
<td>.265</td>
<td>.115</td>
<td>3.813E-02 to .492</td>
</tr>
<tr>
<td>REGR factor score 2 for analysis</td>
<td>European</td>
<td>-.118</td>
<td>.206</td>
<td>-.522 to .287</td>
</tr>
</tbody>
</table>
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Figure 7.8: Histogram of the regression factor scores for the anxiety dimension

Figure 7.9: Histogram of the regression factor scores for the benefits dimension
CHAPTER SEVEN: STUDY III - ATTITUDES TOWARDS USING CAS

Figure 7.10: Scatter plot of regression factor scores of anxiety versus benefits with markers set by age

Figure 7.11: Scatter plot of regression factor scores of anxiety versus benefits with markers set by sex
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Figure 7.12: Scatter plot of regression factor scores of anxiety versus benefits with markers set by number of years in Australia

Figure 7.13: Scatter plot of regression factor scores of anxiety versus benefits with markers set by language spoken at home
7.4 Discussion of findings

7.4.1 Findings from the quantitative analysis of data

The factor analysis as mentioned before produced two constructs: Anxiety: Dimension 1 (consisting of seven questionnaire items 1, 2, 7, 9, 10, 11, 12, 13, 15, and 19; and Benefits: Dimension 2 (consisting of eight questionnaire items 4, 5, 6, 8, 14, 16, 17, and 20). The mean scores for both dimensions (namely anxiety and benefits) were calculated and results were sorted by age, sex, number of years and language spoken, the results of which are summarised in the tables below. A discussion of the analysis for the number and percentage of responses is reported below.

Table 7.6: Data summary statistics by age

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>%</th>
<th>benefits &gt; anxiety</th>
<th>benefits &lt; anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-school leavers (1)</td>
<td>269</td>
<td>88</td>
<td>205</td>
<td>64</td>
</tr>
<tr>
<td>Mature-age students (2)</td>
<td>65</td>
<td>11</td>
<td>52</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 7.6 shows that both high-school leavers (76%) and mature age students (80%) strongly favour computers as a tool for understanding concepts as well as for making learning more enjoyable. Also, the majority of both male (75%) and female (79%) students seemed to hold the same view, that using Mathematica as a tool gives better understanding of concepts and a more enjoyable learning experience (see Table 7.7).

Table 7.7: Data summary statistics by sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>N</th>
<th>%</th>
<th>benefits &gt; anxiety</th>
<th>benefits &lt; anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (1)</td>
<td>304</td>
<td>78</td>
<td>227</td>
<td>69</td>
</tr>
<tr>
<td>Female (2)</td>
<td>38</td>
<td>19</td>
<td>30</td>
<td>8</td>
</tr>
</tbody>
</table>

In relation to the number of years students had spent in Australia (Table 7.8), a clear majority of both recent immigrants, i.e. students who had been in Australia for 5 years or less, and Australian residents (i.e. students who spent 6 years or more in Australia)
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appeared to favour *Mathematica* as a tool for making learning more enjoyable for better understanding of concepts (75% and 78% respectively).

Table 7.8: Data summary statistics by number of years in Australia

<table>
<thead>
<tr>
<th>Number of Years</th>
<th>N</th>
<th>%</th>
<th>benefits &gt; anxiety</th>
<th>%</th>
<th>benefits &lt; anxiety</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent Immigrants (1)</td>
<td>61</td>
<td>18</td>
<td>46</td>
<td>75</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Australian Residents (2)</td>
<td>277</td>
<td>81</td>
<td>216</td>
<td>78</td>
<td>61</td>
<td>22</td>
</tr>
</tbody>
</table>

Finally, in relation to students' cultural background and language spoken at home, the results were interesting (see Table 7.9). For all language groups, the finding was consistent - the majority of students agreed that computers are a useful tool to aid in understanding and learning, and students in this category indicated a greater level of self-confidence in using computers.

Table 7.9: Data summary statistics by language spoken at home

<table>
<thead>
<tr>
<th>Language Spoken</th>
<th>N</th>
<th>%</th>
<th>benefits &gt; anxiety</th>
<th>%</th>
<th>benefits &lt; anxiety</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>English (1)</td>
<td>131</td>
<td>38</td>
<td>102</td>
<td>78</td>
<td>28</td>
<td>21</td>
</tr>
<tr>
<td>Middle Eastern (2)</td>
<td>32</td>
<td>9</td>
<td>19</td>
<td>59</td>
<td>13</td>
<td>41</td>
</tr>
<tr>
<td>Asian (3)</td>
<td>146</td>
<td>42</td>
<td>116</td>
<td>79</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>European (4)</td>
<td>32</td>
<td>9</td>
<td>25</td>
<td>78</td>
<td>7</td>
<td>22</td>
</tr>
</tbody>
</table>

The results are consistent across the board. That is to say, across all the four demographic variables, it can be seen that students appreciate and value the benefits of using computer algebra systems such as *Mathematica*. They also acknowledge the anxiety associated with using a new software program, but as the data shows, the benefits far outweigh the negative aspects of using CAS.
7.4.2 How students perceive learning of mathematics using computer algebra systems

Interviews with students were transcribed and responses were coded into themes. In regard to students' perceptions about the use of the computer algebra system, Mathematica, there were two views held by students. The first view that students held was that Mathematica is a sophisticated number cruncher and a tool for calculation, or as Winslow (2003) suggests - pragmatic issues relating to the use of CAS, concerning the competencies that students need in present and future mathematics-related practice, where CAS is or could be a relevant tool – as evidenced by these quotes:

[Quote from student!]: I guess computers probably just gives you an idea of how accurate or like how to draw graphs accurately and things like that, the thing with Mathematica is that It's like more of an actual language that you've got to learn to be able to write so that in itself is kind of a bit of a waste of time, but Mathematica has got its own separate language that you've got to try and figure out to be able to like draw up stuff, so in that sense I think it's kind of a waste of time, but it's good that you can have something where you can put your values and you can get like a precise graph or something like that where you can read off and see 'OK, this is how it's done', but otherwise, in having to learn the actual language for Mathematica it's kind of, you know, pointless I think.

[Quote from student]: I think Mathematica and other math-related programs is useful, because in our future engineering work, instead of sitting for hours doing our calculations, Mathematica can do it for us in minutes.

[Quote from student]: Oh, it's fantastic! It takes out a lot of the hard work I suppose, depending on what using, like you got things like Mathematica, I suppose when you've got to plot something particularly because some, yeah, like power series or whatever some of those you just, you could sit there and plot it yourself but it's take you all year sort of thing, by the time you sub in the values, definitely it helps a lot in that sense you learn a bit from it too vaguely, like with graphs you do, but you don't want to become too reliant on it otherwise it's going to kick you backwards, and then when you do have to do something without the computer you're going to be up the creek a bit...
CHAPTER SEVEN: STUDY [II] – ATTITUDES TOWARDS USING CAS

The second view that students held was that Mathematica can be used as an aid for learning and understanding concepts. Students that held this view also see Mathematica as a sophisticated number cruncher with powerful calculation capabilities. The quotes are in response to interview questions 7 and 8 (see chapter 4). Question 7 asked students if using computers helped in the learning of mathematics and question 8 asked if using Mathematica helped their understanding of mathematics. Winslow (2003) suggests that these are didactical views or issues – issues concerning the actual or potential impact of CAS use on student learning of mathematics:

[Quote from student]: In all honesty no mainly because in this subject there has been no structure to the maths labs. Basically we have been working by ourselves with the aid of the Mathematica lecture book, and if we came across any problems we have our tutor to help us. I believe that if the weekly labs were structured in such a way that certain exercises were provided weekly which relates directly to the previous lecture undertaken would enable myself to understand the mathematics (similar to how programming subject labs are structured). As unfortunately the only reason for us using Mathematica this semester is to undertake the assignment which I know a lot of people are struggling with (and who attended the labs weekly) as we are not 100% sure of how to go about implementing a problem in Mathematica particularly the worded questions...

[Quote from student]: The computer it’s good, but I think you understand more when you’re writing, like if I want to graph something, I’d think it would be easier, or I’d understand more if I graphed it on paper than actually on computers, because like on computers, you just plug it in, you just have to write in the values and you know what you’re talking about but it’s just more of a substitution into the computer where you’ve got to draw up the graph, you’ve have to see, have to plot it yourself...

[Quote from student]: I believe it does, like what we’re doing now, where we’ve got what we’ve had two labs in this semester so far, it’s been good because its more applying what you’ve learnt as opposed to using the computer to learn, which I think is a better concept because you want to get the basics before you suddenly jump in and go... plot this... so because then you can have a look at what’s going on, but then being able to plot where you’re doing, oh whatever you know get someone else to double check, it’s always good to double check just because if you’re doing it wrong then you’ll know and you’ll go back and do it again, whereas if you had no idea, you’d sit there going ‘OK I’ve got it right’, then you find you’re doing it completely wrong... yeah you losing out in the long run so...
CHAPTER SEVEN STUDY III - ATTITUDES TOWARDS USING CAS

7.5 Implication of findings

The analysis of the quantitative data was consistent across all demographic information collected. A clear majority of both male and female students, high-school leavers and mature age students, recent immigrant and Australian residents and students from all 4 language backgrounds appeared to hold the view that Mathematica is a useful tool that can aid in the process of understanding concepts, and can make learning a more enjoyable experience. The findings also show that a few students indicated that they suffer from computer anxiety, as evidenced from the responses and appear to feel positively self-confident about being able to use computers.

The qualitative data revealed two clearly emerging themes regarding the use of computers in mathematics instruction - a low-level theme where students viewed Mathematica as a sophisticated number cruncher, and a second, higher-level theme where students were of the opinions that Mathematica helped their understanding of concepts.

So, how is it that greater implementation of CAS into university mathematics courses is not apparent, especially since the attitudes towards CAS appear to be favourable? The reasons seem to involve all players - academics, students and administrators. One of the prerequisites for successful introduction of CAS is that a substantial number of academics need to use it regularly in their teaching, and that they require students to use it as well. Academics have reasons for not using CAS, such as lack of time for both themselves and students, or lack of adequate hardware and software. Most courses cover a lot of material, and few academics like to spend time teaching CAS as an additional topic in their classes.

Also, regulations for universities make it difficult to use CAS, therefore students do not see the benefits of using CAS. It appears that many academics have no pedagogical reason for use of CAS. We believe that academics need a much clearer pedagogical reason for using CAS, especially those that do not use it often. In particular, they should decide whether to teach the tools that are being used in industry, or to emphasise programs that help students understand concepts.
**7.6 Synopsis of chapter**

This chapter has looked at the data on students’ Views about using computers, in particular CAS such as *Mathematica*. The effects of age, gender, language background and length of stay in Australia have been investigated. The results were obtained from both a qualitative and quantitative study. The results obtained from both were interesting in certain regards. The student quotes revealed hierarchical themes regarding the use of computers in mathematics instruction - a lower level theme where students viewed *Mathematica* as a sophisticated number cruncher and a second higher level theme where students were of the opinion that *Mathematica* not only could be used as a sophisticated number cruncher but also to help in their understanding of concepts. Arguments for and against use of CAS in the literature are many, most of them pedagogical but also some practical (Coupland, 2000; Cretchley, 2001). This study has shown in this study the desirable effects of using *Mathematica*, which supports the findings of many existing research studies, but not so many of these are conducted in the engineering education domain where mathematics is a service subject.

There are many inferences that can be drawn regarding using computers in the teaching and learning of mathematics at university. As students in this study pointed out, it is very exciting, enjoyable and productive to use computers in class. Some of the students are keen to use computers, so the environment becomes more conducive for learning. Due to this, students’ natural curiosity can be utilised to its fullest potential because they are keen to explore and discover. Sound social relationships develop as they discuss their findings amongst each other. They take a certain degree of responsibility of their own learning.

The mean scores were slightly significant with the average score for the *anxiety* dimension being 3.5 and the average score for the *benefits* dimension being 4.9. The scatter plots of the two dimensions plotted against each other with markers set by each of the four variables of interest displayed a negative relationship. The multivariate analysis of variance (MANOVA) produced statistically significant results for gender (*p*-value = 0.01) and language spoken at home (*p*-value = 0.02). There was a 0.2 difference in the marginal means for the *anxiety* dimension with females indicating greater anxiety.
than males. Looking at language/cultural diversity, the results were interesting. There was a 0.6 difference in students' opinions. Middle Eastern students displayed the highest mean (mean = 3.9) while European students displayed the least (mean = 3.3). Native English speakers highly favoured the use of computers through their scoring on the benefits of using computers (mean = 4.9) in comparison to their Middle Eastern counterparts (mean = 4.2). A different analysis was also done in regards to the number of instances where the mean score for the anxiety dimension was greater (or less) than the mean score for the benefits dimension. The results were tabulated in Tables 7.6-7.9 and sorted by the four variables of interest. Across all the four variables, the number (and percentage) of responses that appeared to favour the benefits of using computers was greater than that of the drawbacks in relation to anxiety.

In summary, the findings were uniform across all the four demographic groups and are listed below:

a. Both high-school students and mature-age students favoured using computers as a tool for understanding concepts and acknowledged the fact that it made learning more enjoyable.

b. Both male and female students held exactly the same view that using the software helped in their understanding of concepts and made learning pleasurable.

c. Both recent immigrants as well as their Australian resident counterparts Views Mathematica as a tool that helped in the learning and understanding of various concepts.

d. Finally, while students from all four language groups indicated that using Mathematica helped their understanding of various concepts, only a smaller proportion of students of Middle Eastern descent held this opinion compared with a higher proportion of students of Asian, Indian, and European descent as well as those from an English speaking background.

Change can produce stress and, unless acknowledged and managed appropriately, it can inhibit the learning process and subsequent success of the innovation. The change required will be greatest where it conflicts with students' previous educational experiences and current conceptions of learning. This study has shown that some students, in particular female students and Middle Eastern students, have high anxiety...
about the use of computers in their learning of mathematics (from the multivariate analysis. This should be acknowledged in teaching and learning, and support offered to alleviate the anxiety.

This study suggests that if students are to use CAS, it is important that it be blended into their everyday class work. They must therefore be introduced to CAS in a systematic way, and they need to be required to use it. Computer algebra systems (CAS) such as Mathematica, challenge the traditional mathematics curriculum, causing many questions to arise. For instance, what will be the place of memorising algorithms in the future? Will we as academics still require students to be able to 'integrate by parts' using pen-and-paper techniques? Can we broaden the mathematics curriculum to include more generic skills such as mathematical modelling if we allow CAS to perform the algebra and calculus manipulations? Also, the role of assessment will change in the future mathematics curriculum. These are just a few of the issues that mathematics education researchers have to consider.
Chapter 8

Study FOllr: Students' attitudes toward group-based assessment and the design of mathematical tasks that encourage working together and collaboratively: Results and analysis of findings

8.1 Introduction

This chapter takes up the investigation of students' attitudes towards being assessed as a group, as well their opinions about the types of tasks that were set within the study for the collaborative tutorials (and labs). It is hoped that the findings from this fourth study will inform the practices of both academics and students and, in particular, will identify what is required for the successful evaluation of learning conducted in collaborative group settings. Implications of such methods in mathematics instruction in higher education will be explored in chapter nine, along with a discussion of implications of the findings from the other three studies.
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

The research questions being posed in this chapter are as follows:
1. What are tertiary students' attitudes towards the assessment of group-based work?
2. What impact do age, gender, number of years in Australia, and language spoken have on students' attitudes toward the assessment of group work?

8.2 Rationale for the study

Research suggests that benefits can be accrued through academic group work. It is reasonable to expect that there would be some diversity of opinion among students regarding the requirement that they participate in groups to complete academic work. For instance, Butts (2000) noted that it is common for students not to enjoy group work. A certain dilemma arises: group work is demonstrated to have highly beneficial results, but is not enjoyed by all students. If we hope to improve student attitudes towards group work, it is important to first explore the issues such as assessment that might influence such attitudes. This information can then be used to address student concerns and to explore possible techniques for improving students' attitudes and the effectiveness of groups.

Traditional, individual-based projects are easy to attribute to one student. However, when evaluating a group task or project, academics face a more difficult problem - do all students receive the same grade and, if so, what system should we have in place for determining how to differentiate the contribution of one student from that of his or her group members? This chapter discusses the concerns that students raise in regard to the assessment of collaborative-based activities.

8.3 Significance of group work and its assessment

Groups...hold the key to solving such societal problems as racism, sexism, and international conflict. Because groups are building blocks of society, any attempt to change society will succeed only if the groups within that society change (Forsyth, 1999, pxi)
CHAPTER EIGHT: STUDY IV – ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

A way to prepare future employees is by having them work in groups in academic settings (Thomas, 2001). Group work is believed to be beneficial not only in a work environment but can also have many positive results in academic settings (DePree, 1998; Thomas, 2001). Why then are such methods not widely integrated into mathematics instruction at the tertiary level? How do we promote these methods amongst academics and students? What do we need to do to ensure implementation of appropriate assessment methods for group-based work?

8.4 Collection of data for this study

Based on the assumption that students' opinions about group work are linked to the degree to which students' feel that their efforts are effective and lead to desired results, this chapter investigates difficulties students have regarding the assessment of group work, since assessment plays an important role in a students' success at university. As mentioned before, students were involved in working collaboratively all through one semester during weekly 1-hour tutorials.

There were 7 tutorial session and 3 laboratory sessions scheduled for the duration of the semester (see Appendix A10 for sample tutorial). The marks awarded for these sessions accounted for 10% of the final grade. In addition to these sessions, there was one assignment (worth 25%) and a final examination (worth 65%). Tasks were carefully designed such that they would encourage discussion and promote collaboration. A total of 344 students completed a questionnaire that sought their attitudes towards being assessed as a group.

In addition to this, twenty students comprising six female and fourteen male students consented to be interviewed. To give readers an idea of how the group tasks were assessed, Table 8.1 contains a sample assessment breakdown for one such tutorial. Each of the weekly tutorials consisted of questions across four areas - technique, concept, language, and application.
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Table 8.1: Assessment breakdown for sample collaborative-based task

<table>
<thead>
<tr>
<th>Allocation of marks for a sample tutorial</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>0</td>
</tr>
<tr>
<td>Participation</td>
<td>0</td>
</tr>
<tr>
<td>Technique</td>
<td>0</td>
</tr>
<tr>
<td>Concept</td>
<td>0</td>
</tr>
<tr>
<td>Language</td>
<td>0</td>
</tr>
<tr>
<td>Application</td>
<td>0</td>
</tr>
<tr>
<td>Minimum mark that can be attained</td>
<td>0</td>
</tr>
<tr>
<td>Maximum mark that can be attained</td>
<td>10</td>
</tr>
</tbody>
</table>

8.5 Results

The results will be discussed in two parts. Part I will outline the results from the interviews that were conducted with students. Only responses in relation to assessment of group work are reported in this chapter. The interviews were audio-taped, transcribed, analysed, and categorised into themes. It should be noted that some of these quotes have been used before in chapter six when discussing students’ issues with group work and have been repeated here to emphasise the case relating to the assessment of group-based work.

8.5.1 Part I of results: Interview responses

A major issue that arose was the case of unequal workload. One can imagine that it is annoying when one member of a group does nothing at all to contribute to the task on hand. If one group member does not contribute as much as the others, then this will often leave the other members frustrated and the student who is not contributing will not really learn very much. This opinion was voiced by a student:

[Quote from student]: She doesn’t do much so she’s getting the marks and she’s not contributing... that’s a bit annoying sometimes and that – but can’t really do anything about it.
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

When students are placed into groups, many of the hard-working students do all of the work and the laid-back students do little or nothing, but still receive the same grade. Not everyone in the group will participate and some students rely on others to do the work for them. These students usually receive the same grade nonetheless, which may be seen as unfair to the students in the group who did all of the work, as one student pointed out:

[Quote from student]: I think well, I can imagine that you know some of as sit down and do it and someone doesn’t and they’re like put my name on it or something and that does get a bit annoying because they don’t contribute and so that’s one thing that one negative aspect of group work - the ones that don’t contribute kind of get the marks or not the marks you really want to get.

The other side of the coin is when one member in the group is the only one that is capable of doing part of or all of the work that is set out for the group, and the rest just sit back and watch. This can get very frustrating if this one student realises that he or she is doing all the work, as one student commented:

[Quote from student]: ... it's not fair - like one boy sitting there can do all the questions and three other boys can watch or girls you know and I don't think that unless you have teacher that can monitor questions and all kids putting their name down on what they did - it's not fair - it's good for students like me who possibly aren't as gifted at maths as others because it pulls our marks up whereas say student X for instance, his marks will be pulled down because he’ll be relying on myself and student Y to do questions whereas he only can do two questions in a set amount of time and If we did the other two and we don’t get as high a mark as he would, we’re sort of pulling him down so in a way it's sort of striking up an equilibrium between gifted and not so gifted students.

This comment was made by a student in a group of four members:

[Quote from student]: Hey, it's great because I've been riding on the back of intelligent people. I'd be really annoyed if I was in a group that didn’t have as intelligent people because not only would I get frustrated with things I couldn’t do, and the fact that nobody else could do them so not only would we do badly but I have no possibility of having someone in my group explain it to me, so the assessment for me at the moment is really advantageous but I can see how it can be really bad if the tables had turned certainly.
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Another student had this to say about why she preferred to work alone in comparison to working in a group when it came to being assessed at the end of each tutorial session:

[Quote from student]: I prefer to work alone a lot of the times, mainly because [find that I need my peace and quiet, so every time we work in a group, progress seems a lot slower and especially working as a team – we definitely have different opinions, some people do more some people do less so I think individual assignments are better. You can't say it's not fair how they give the same mark to everyone in the group but it's not always contributes as much to get that mark.

These two quotes come from the same student who sat on the other side of the fence, i.e. this student regards himself as not mathematically able to do all the tasks and is grateful to the members in his group that help him achieve the results he has been achieving:

[Quote from student]: I'm doing well in them but I have a lot to thank for my group for that because my maths isn't as good as what it should be - I find that my group is pulling me up and I am achieving good results and I am putting in... like I am actively putting in and helping do questions but I find that I wouldn't get anywhere near as a good a result without my group.

[Quote from the same student]: No it's not fair... good for students like me who possibly aren't as gifted at maths as others because it pulls our marks up.

Another aspect that was raised was the fact that there is not enough time to complete the tasks, either because of the fact that the questions could not be completed in an hour, or because there are not enough members in the group to complete the tasks, as this student pointed out:

[Quote from student]: I think it's unfair that we are disadvantaged - when there are not enough people in our group - I think it's unfair because even if we know how to do the questions, because of the lack of time that was left, we were unable to finish that question.... That's what's frustrating the most - when you get a bunch of questions that you can solve and you don't have enough time but you know you could, that it's no fault of yours, its frustrating for us.

There were also responses from students regarding positive aspects of being assessed as a group. Some of the quotes from students follow:
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

[Quote from student]: Individually a person may not achieve as well as what they would if they were in a group – you know how they throw around ideas so you will produce a better answer so! I guess you can’t actually assess the individual by using group-based activity so it could be unfair to some members because they might be better than others... and people fooling around, but that’s the whole point of group-based activity to help each other out and everyone learns.

[Quote from student]: That’s a good way of doing it! I believe, like especially participation is important because otherwise you’re going to have someone bludging, there’s always someone who’s going to not do something, it’s the way of life but [laugh!] I think it works well what they’re doing, it’s a decent assessment.

[Quote from student]: I find that good as a group... because you go and ask other people and you get help from them and only thing is that you’re doing it by yourself and I find that that way you learn more... everyone’s input sort of counts towards one’s mark and sometimes it’s not really accurate! I guess because some of the better students will push up the lower grade students, so I don’t know whether they find it a bit I guess like a hindrance to them, but I find it’s good where everyone can get like you know round about you know a decent mark.

(Quote from student): Providing that the tutorial teacher is I suppose aware of everybody and what goes on then yes! I think it would be fair, but I don’t think it’s practical for such a big... how can he be aware of every student whether or not they’re doing work you know especially when people are asking questions - possibly if there were more tutors then it would be fair...

There were students that used the resources of the group to get correct answers to problems but may not have understood the procedures for solving the problems and possibly did not try. They were not actively engaged in constructing solutions to problems, but were merely using the work that other students had done.

Yet there were others who had difficulty understanding how to solve the problems and used the resources of the group to obtain the correct answer and to understand the problem-solving procedures. Without the collaborative experience, they probably would not have been able to solve the set tasks.
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Research in instructional settings shows, that there are many factors influencing group functioning and group performance. Factors shown to influence group processes in the classroom include composition of the group on characteristics such as ability, age, gender, cultural background, preparation of students for group work, and ways in which group interaction is structured (Webb, 1991).

Positive effects on group functioning and better attitudes towards group based assessment can be aided by ensuring that every group has at least one able member; rewarding groups on the basis of the performance of all group members; providing students with training in communication and interpersonal skills; giving them practice in collaborating with others; requiring them to discuss issues; and asking each other probing questions. Intentionally or unintentionally, groups may differ widely on these factors.

8.5.2 Part II of results: Attitudinal questionnaire

Students were presented with a questionnaire of 15 items that asked about their attitudes towards group-based assessment, by circling the number on a five-point scale (where "1 = strongly disagree", "2 = disagree", "3 = neutral", "4 = agree", and "5 = strongly agree") that best reflected their perceptions (see Appendix A7 for questionnaire items). The questionnaire items that were used in this study were written for this study. A principal component factor analysis with varimax rotation of 15 items generated 2 constructs or factors:

1. **Dimension I: Negative aspects** (encompassing negative aspects of being assessed as a group) consisting of questionnaire items 2, 4, 5, 7, 8, 1a, 11, 12, 14, and 15 (item 9 was loading equally under both factors and was not included in the analysis).
2. **Dimension 2: Group processes** (see Table 8.1 for the factor analysis output) consisting of questionnaire items 3, 6, and 13 (item 1 was loading equally under both factors and hence was not included in the analysis).

This two-factor model accounted for just 35% of the item variation (adjusted $R^2 = 34.92$). In other words, students perceived that objectives for setting group-based work accounted for much less than half of the variance in gains. The
internal consistency reliability was not very high for the two factors, with Cronbach’s alpha of 0.6944. Cronbach’s alpha is a measure of strength, where 1.0 suggests a perfect correlation. Figure 8.1 provides the scree plot for the two factors while Table 8.2 is the rotated component matrix for the dimensions. Table 8.3 lists the items in the questionnaire administered to students.

Table 8.2: Principal component factor analysis for group-based assessment

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction Sums of Squared Loadings</th>
<th>Rotation Sums of Squared Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of Variance</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>2</td>
<td>1.562</td>
<td>10.412</td>
<td>34.921</td>
</tr>
<tr>
<td>3</td>
<td>1.133</td>
<td>7.555</td>
<td>42.476</td>
</tr>
<tr>
<td>4</td>
<td>1.046</td>
<td>6.977</td>
<td>49.453</td>
</tr>
<tr>
<td>5</td>
<td>.981</td>
<td>6.542</td>
<td>55.995</td>
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<tr>
<td>7</td>
<td>.893</td>
<td>5.951</td>
<td>68.016</td>
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<tr>
<td>8</td>
<td>.802</td>
<td>5.346</td>
<td>73.362</td>
</tr>
<tr>
<td>9</td>
<td>.745</td>
<td>4.964</td>
<td>78.326</td>
</tr>
<tr>
<td>10</td>
<td>.668</td>
<td>4.451</td>
<td>82.777</td>
</tr>
<tr>
<td>11</td>
<td>.625</td>
<td>4.170</td>
<td>86.946</td>
</tr>
<tr>
<td>12</td>
<td>.569</td>
<td>3.792</td>
<td>90.739</td>
</tr>
<tr>
<td>15</td>
<td>.407</td>
<td>2.715</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.

Figure 8.1: Scree plot
CHAPTER EIGHT: STUDY IV-ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Table 8.3: Rotated component matrix of the two factors

<table>
<thead>
<tr>
<th>Rotated Component Matrix</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q11</td>
<td>.714</td>
<td>6.334E-02</td>
</tr>
<tr>
<td>Q12</td>
<td>.701</td>
<td>4.527E-02</td>
</tr>
<tr>
<td>Q10</td>
<td>.681</td>
<td>8.240E-02</td>
</tr>
<tr>
<td>Q7</td>
<td>.611</td>
<td>-.362</td>
</tr>
<tr>
<td>Q8</td>
<td>.565</td>
<td>-.248</td>
</tr>
<tr>
<td>Q4</td>
<td>.555</td>
<td>-8.34E-02</td>
</tr>
<tr>
<td>Q5</td>
<td>.547</td>
<td>-5.42E-02</td>
</tr>
<tr>
<td>Q15</td>
<td>.509</td>
<td>-9.34E-02</td>
</tr>
<tr>
<td>Q2</td>
<td>.464</td>
<td>3.012E-02</td>
</tr>
<tr>
<td>Q14</td>
<td>.456</td>
<td>3.592E-02</td>
</tr>
<tr>
<td>Q9</td>
<td>.254</td>
<td>7.736E-02</td>
</tr>
<tr>
<td>Q3</td>
<td>-.132</td>
<td>.750</td>
</tr>
<tr>
<td>Q6</td>
<td>-.136</td>
<td>.615</td>
</tr>
<tr>
<td>Q13</td>
<td>.147</td>
<td>.578</td>
</tr>
<tr>
<td>Q1</td>
<td>.269</td>
<td>.314</td>
</tr>
</tbody>
</table>


a. Rotation converged in 3 iterations.

Table 8.4: Questionnaire items

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I would rather choose my fellow group members than be allocated to a group by a tutor</td>
</tr>
<tr>
<td>2</td>
<td>Automatically granting each group member the same grade for a group task is unfair</td>
</tr>
<tr>
<td>3</td>
<td>I think it is important that I should take part in a group task as part of my studies</td>
</tr>
<tr>
<td>4</td>
<td>Group assessment should be used ONLY to measure an individual’s ability to work in a group</td>
</tr>
<tr>
<td>5</td>
<td>Group assessment tends to ‘bunch’ the marks for a given cohort of students</td>
</tr>
<tr>
<td>6</td>
<td>Peer assessment methods are a fair way of distributing marks in a group task</td>
</tr>
<tr>
<td>7</td>
<td>I would rather undertake an individual task than a group task</td>
</tr>
<tr>
<td>8</td>
<td>I have not yet met a method of group assessment which is fair to all group members</td>
</tr>
<tr>
<td>9</td>
<td>With individual assessment in groups, group members can become competitive with each other and not share their resources and ideas</td>
</tr>
<tr>
<td>10</td>
<td>Groups assessments allow students to 'hide' more easily than with individual tasks</td>
</tr>
<tr>
<td>11</td>
<td>Group assessments tend to penalise able students</td>
</tr>
<tr>
<td>12</td>
<td>Group assessment methods are not as reliable as individual assessment</td>
</tr>
<tr>
<td>13</td>
<td>Before undertaking a group assessment students should learn how to work in a team</td>
</tr>
<tr>
<td>14</td>
<td>There are often more disagreements and conflicts over the allocation of tasks</td>
</tr>
<tr>
<td>15</td>
<td>Groups assessment tend to benefit less able students</td>
</tr>
</tbody>
</table>
Figures 8.2 and 8.3 are histogram plots of the two dimensions (or factors) obtained from the factor analysis. *Negative* represents the mean score for dimension/factor 1 (namely, *negative aspects of group-based assessment*) for each student, while *grprocess* represents the mean score for dimension/factor 2 (namely, *group processes*).

**Figure 8.2:** Histogram of average scores for *negative aspects*

**Figure 8.3:** Histogram of average scores for *group processes*
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There was a slight difference in the average scores for each of the two factors, with the average score for _negative_ being 3.56 and the average score for _group process_ being 3.27. Figures 8.4, 8.5, 8.6, and 8.7 are scatter plots of _negative aspects_ (average score of the 12 items in dimension 1) versus _group processes_ (average score of the 3 items in dimension 2) respectively plotted by age, gender, number of years spent in Australia and language spoken at home.

Figure 8.4: Scatter plot of _negative aspects_ versus _group processes_ by age

Figure 8.5: Scatter plot of _negative aspects_ versus _group processes_ by sex
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Figure 8.6: Scatter plot of negative aspects versus group processes by number of years in Australia

Figure 8.7: Scatter plot of negative aspects versus group processes by language spoken at home
Each of the four scatter plots of negative versus grprocess above show a fairly independent relationship with no obvious positive or negative relationship, which is as desirable result, since we are trying for independent dimensions. Next, a multivariate test using the general linear model was performed using negative and grprocess as dependent variables and age, sex, number of years, and language spoken as fixed factors (see Table 8.4 for output). The analysis showed that lang is marginally significant ($p = 0.09$).

There was no significant difference in the means for either of the two dimensions across the two age groups, the two gender groups or even between recent immigrants and Australian residents (see Tables 8.5a-b and 8.6a-b). However, with respect to language spoken at home, results were a little interesting as indicated by the marginally significant p-value.

There was a 0.3 difference in the mean score of Middle Eastern students (mean = 3.6) and European students (mean = 3.3) in the negative dimension, indicating that Middle Eastern students displayed a greater concern over the negative aspects of group-based assessment. What was surprising is that the mean score for the Middle Eastern group of students was the highest (mean = 3.4) in the group process dimension as well in comparison to the Asian and Indian students whose mean score was the lowest at 3.2.
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Table 8.5: Multivariate test for negative and grprocess using age, sex, number of years and language spoken as fixed factors

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillai's Trace Value</th>
<th>Wilks' Lambda Value</th>
<th>Hotelling's Trace Value</th>
<th>Roy's Largest Root Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>SL</th>
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</thead>
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<tr>
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<td>.063</td>
<td>14.882</td>
<td>14.882</td>
<td>2343.899*</td>
<td>2343.899*</td>
<td>2343.899*</td>
<td>.000</td>
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<tr>
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<td>.002</td>
<td>.346*</td>
<td>2.000</td>
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<td>1.795</td>
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<td>632.000</td>
<td>.098</td>
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<td>.098</td>
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<tr>
<td>YEARS</td>
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<td>1.161*</td>
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<td>.315</td>
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<td>6.000</td>
<td>632.000</td>
<td>1.792</td>
<td>6.000</td>
<td>628.000</td>
<td>.098</td>
</tr>
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</table>

a. Exact statistic
b. The statistic is an upper bound on F that yields a lower bound on the significance level.
c. Design: Intercept+AGE+SEX+YEARS+LANGUAGE

Table 8.6a-b: Estimated marginal means for negative and grprocess by age, and sex respectively

1. AGE

<table>
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<tr>
<th>Dependent Variable</th>
<th>AGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
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<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
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<td>high-school leavers</td>
<td>3.549</td>
<td>.079</td>
<td>3.393</td>
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<tr>
<td>mature age students</td>
<td>3.536</td>
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<td>3.340</td>
<td>3.731</td>
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<tr>
<td>GRPROCES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high-school leavers</td>
<td>3.231</td>
<td>.077</td>
<td>3.079</td>
<td>3.383</td>
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<tr>
<td>mature age students</td>
<td>3.309</td>
<td>.097</td>
<td>3.118</td>
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2. SEX

<table>
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<th>SEX</th>
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<td>Male</td>
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<td>Female</td>
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</table>
CHAPTER EIGHT: STUDY IV—ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Table 8.7a-b: Estimated marginal means for negative and grprocess by number of years and language spoken respectively

3. YEARS

<table>
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<tr>
<th>Dependent Variable</th>
<th>YEARS</th>
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<th>Std. Error</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEGATIVE</td>
<td>Recent migrants</td>
<td>3.607</td>
<td>.104</td>
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<td></td>
<td>Australian residents</td>
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<td>.077</td>
<td>3.327</td>
<td>3.628</td>
<td></td>
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<tr>
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<td>.102</td>
<td>3.021</td>
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<td></td>
<td>Australian residents</td>
<td>3.320</td>
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<td>3.173</td>
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4. LANGUAGE

<table>
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<th>Upper Bound</th>
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<tbody>
<tr>
<td>NEGATIVE</td>
<td>English speakers</td>
<td>3.533</td>
<td>.091</td>
<td>3.354</td>
<td>3.712</td>
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<td>Middle eastern</td>
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<td>3.361</td>
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<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>3.679</td>
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<td>3.332</td>
<td>.131</td>
<td>3.074</td>
<td>3.591</td>
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<tr>
<td>GRPROCES</td>
<td>English speakers</td>
<td>3.264</td>
<td>.088</td>
<td>3.090</td>
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<td>Middle eastern</td>
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<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>3.176</td>
<td>.072</td>
<td>3.034</td>
<td>3.317</td>
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<tr>
<td></td>
<td>European</td>
<td>3.256</td>
<td>.128</td>
<td>3.004</td>
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</table>

In reference to the definition of the two dimensions, I used an actual combination of questions as defined by the factor analysis and created scatter plots of the new scores, namely regression factor scores for negative and regression factor scores for grprocess with markers set by age, sex, number of years and language spoken (see figures 8.8, 8.9, 8.10, and 8.11). This time the two dimensions produce a graph that is much more like two independent variables should be.

1 Regression factor scores for the negative dimension is denoted as REGR factor score 1 for analysis 1 in the scatter plots and regression factor scores for the grprocess dimension is denoted as REGR factor score 2 for analysis 1 in the scatter plots.
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Figure 8.8: Scatter plot of regression factor scores of negative versus $g_{process}$ with markers set by age

Figure 8.9: Scatter plot of regression factor scores of negative versus $g_{process}$ with markers set by sex
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Figure 8.10: Scatter plot of regression factor scores of negative versus grprocess with markers set by number of years in Australia

Figure 8.11: Scatter plot of regression factor scores of negative versus grprocess with markers set by language spoken at home
8.5.3 Students' performance in the subject

- Part I: Performance of students who were interviewed

This section of the chapter deals with the results from the final examination as well as the results from the weekly tutorial and laboratory sessions. Although it is possible to provide the final grades for all 436 students that were enrolled in the first-year subject, it is far more interesting to investigate, in particular, the assessment results of the 20 students that were interviewed, because for this cohort, not only do we have the final examination marks, the tutorial and laboratory results, we also have their responses from interviews conducted relating to their attitudes towards computers, group work and its assessment.

Out of the 10 sessions allocated for tutorials or laboratory sessions, seven were tutorial sessions (where activities done during the 1 hour were marked out of 10) and three were laboratory sessions (each being marked out of 5). These 10 sessions contributed 10% towards the final grade. The final examination was worth 65% and the remaining 25% consisted of a semester test (15%) and an assignment (10%).

Table 8.8: Exam and tutorial results for the students that were interviewed

<table>
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<tr>
<th></th>
<th>Exam</th>
<th>TUTE</th>
<th>DIFF</th>
<th>age</th>
<th>sex</th>
<th>yrs</th>
<th>back</th>
<th>Grade</th>
<th>Tut1</th>
<th>Tut2</th>
<th>Tut3</th>
<th>Tut4</th>
<th>Tut5</th>
<th>Tut6</th>
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<td>2</td>
<td>3</td>
<td>C</td>
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<td>9</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6.9</td>
<td>5.0</td>
<td>7.4</td>
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</tbody>
</table>
Figures 8.12 and 8.13 are histogram plots for the mean marks in the seven tutorial and 3 laboratory sessions respectively. The average mark obtained in the tutorial was 7.04 (maximum mark allocated was 7) while the average mark recorded for the labs was 4.6 (maximum mark allocated was 5).

Figure 8.12: Histogram of mean scores of tutorial sessions

Figure 8.13: Histogram of mean scores of laboratory sessions
Figures 8.14 is a histogram plot of the final examination marks while Figure 8.15 is a histogram plot of the total mark awarded for the tutorial and laboratory sessions. We can see that the average examination mark was 67 (out of 100) while the average score for the tutorials and laboratory sessions was 63 (out of 100).
Figures 8.16, 8.17, 8.18, and 8.19 are scatter plots of the final examination mark plotted against the final tutorial and laboratory marks with markers set by age, sex, number of years in Australia and language spoken at home respectively. From each of these scatter plots we can see that there appears to be a slightly positive trend, which indicates that those who performed well in the final examination also performed well during the semester in the tutorial and laboratory sessions.

Figure 8.16: Scatter plot of examination mark versus tutorial & laboratory marks with markers set by age of students

Figure 8.17: Scatter plot of examination mark versus tutorial & laboratory marks with markers set by sex of students
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Figure 8.18: Scatter plot of examination mark versus tutorial & laboratory marks with markers set by number of years in Australia

Figure 8.19: Scatter plot of examination mark versus tutorial & laboratory marks with markers set by language spoken at home
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Next, a multivariate test using the general linear model was performed using exam and tute_lab as dependent variables and age, sex, number of years, and language spoken as fixed factors (see Table 8.8 for output). The analysis showed that language was marginally significant ($p = 0.09$).

There was no significant difference in the means for either of the two dimensions across the two age groups, the two gender groups or even between recent immigrants and Australian residents (see Tables 8.9a-b and 8.10a-b). The results for the marginal means for these three groups however, are interesting to note as discussed below. In addition, with respect to language spoken at home, results were interesting as indicated by the significant p-value.

Table 8.9: Multivariate test for exam and tute_lab using age, sex, number of years and language spoken as fixed factors

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillai’s Trace</th>
<th>Wilks’ Lambda</th>
<th>Hotelling’s Trace</th>
<th>Roy's Largest Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.970</td>
<td>195.736*</td>
<td>2.000</td>
<td>12.000</td>
</tr>
<tr>
<td>AGE</td>
<td>.298</td>
<td>2.547*</td>
<td>2.000</td>
<td>12.000</td>
</tr>
<tr>
<td>SEX</td>
<td>.269</td>
<td>2.207*</td>
<td>2.000</td>
<td>12.000</td>
</tr>
<tr>
<td>YEARS</td>
<td>.144</td>
<td>1.006*</td>
<td>2.000</td>
<td>12.000</td>
</tr>
<tr>
<td>LANGUAGE</td>
<td>.878</td>
<td>3.388</td>
<td>6.000</td>
<td>26.000</td>
</tr>
</tbody>
</table>

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept+AGE+SEX+YEARS+LANGUAGE
High school students performed better in both the final examination and during the tutorial and laboratory sessions (mean exam mark = 82 and mean tutorial & lab mark = 71) compared with the mature age students, with an average difference of 19 marks in the final exam between the two groups.

Also, among the two genders, female students performed marginally better in both the final exam and during the tutorial and laboratory sessions (mean exam mark = 76 and mean tutorial & lab mark = 74) than their male counterparts. It is to be noted though, that were only 4 female students in the group of 20 that were interviewed.

Table 8.10a-b: Estimated marginal means for exam and tute_lab by age, and sex respectively

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Age</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXAM</td>
<td>high school leavers</td>
<td>82.221</td>
<td>6.369</td>
<td>68.460 - 95.981</td>
</tr>
<tr>
<td></td>
<td>mature age students</td>
<td>63.505</td>
<td>5.544</td>
<td>51.528 - 75.482</td>
</tr>
<tr>
<td>TUTE_LAB</td>
<td>high school leavers</td>
<td>71.382</td>
<td>5.459</td>
<td>59.589 - 83.176</td>
</tr>
<tr>
<td></td>
<td>mature age students</td>
<td>66.020</td>
<td>4.752</td>
<td>55.754 - 76.285</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Sex</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXAM</td>
<td>male</td>
<td>69.341</td>
<td>4.111</td>
<td>60.458 - 78.223</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>76.385</td>
<td>6.676</td>
<td>61.963 - 90.807</td>
</tr>
<tr>
<td>TUTE_LAB</td>
<td>male</td>
<td>62.488</td>
<td>3.524</td>
<td>54.875 - 70.101</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>74.914</td>
<td>5.722</td>
<td>62.553 - 87.275</td>
</tr>
</tbody>
</table>

In regards to the number of years spent in Australia, the results were interesting and unexpected. Recent immigrants (i.e. students who had spent 5 years or less in Australia) performed better in both the final examination and during the tutorial and laboratory sessions (mean exam mark = 78 and mean tutorial & lab mark = 72) compared with the Australian residents. This is an interesting result because it was expected that the Australian residents would perform better than the recent immigrants since they would have to get adjusted in a new country and to a different educational system as well as new learning methods such as the collaborative group work.
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With respect to language spoken at home, the results were fascinating. In both the final examination and tutorial and laboratory sessions, the European students performed much better than students in the other three language groups. In particular, there was a difference of 35 marks between the European students (mean exam mark = 91) and native English speakers (mean exam mark = 56). In regards to performance in the tutorials and labs, students’ marks were only marginally different with students of Asian and Indian background scoring the lowest and European students once again scoring the highest (mean English = 72, mean Middle-Eastern = 65, mean Asian = 62, and mean European = 75).

Table 8.1a-b: Estimated marginal means for exam and tute lab by number of years and language spoken respectively

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>YEARS</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>EXAM</td>
<td>recent immigrants</td>
<td>78.338</td>
<td>7.186</td>
<td>62.814</td>
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<tr>
<td></td>
<td>Australian residents</td>
<td>67.387</td>
<td>4.435</td>
<td>57.806</td>
</tr>
<tr>
<td>TUTE LAB</td>
<td>recent immigrants</td>
<td>72.353</td>
<td>6.159</td>
<td>59.048</td>
</tr>
<tr>
<td></td>
<td>Australian residents</td>
<td>65.049</td>
<td>3.801</td>
<td>56.837</td>
</tr>
</tbody>
</table>

3. YEARS

4. LANGUAGE

- Part II: Performance of all students who participated in the investigation

In this section, I look at the performance of all students that consented to participate. Figures 8.20 and 8.21 show the distribution of marks obtained in the final examination and tutorial and laboratory sessions respectively. This is the distribution for all students enrolled in the first-year subject. (n = 413, 40 missing values). Figures 8.22 and 8.23 also show the distribution of marks obtained in the final examination and tutorial & laboratory sessions respectively. However, the distribution is for all students who
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

completed the questionnaire \((n = 344, n_{\text{exam}} = 325, n_{\text{tute&lab}} = 321)\). The average final exam score was 59 and that of the tutorial and laboratory sessions was 63.

![Histogram of final examination marks of all students enrolled](image1)

**EXAM**

Figure 8.20: Histogram of final examination marks of all students enrolled

![Histogram of tutorial and laboratory marks of all students enrolled](image2)

**TUTE LAB**

Figure 8.21: Histogram of tutorial and laboratory marks of all students enrolled
CHAPTER EIGHT: STUDY IV - ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Figure 8.22: Histogram of final examination marks of all students that completed the questionnaire

Figure 8.23: Histogram of tutorial and laboratory marks of all students that completed the questionnaire
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Figure 8.24 is a scatter plot of the final examination results plotted against the tutorial and laboratory marks for the population of students enrolled in the course. The plot shows a fairly strong positive relationship between the two variables.

![Scatter plot of final examination versus tutorial and laboratory marks for the population of students enrolled in course](image)

Figure 8.24: Scatter plot of final examination versus tutorial and laboratory marks for the population of students enrolled in course

Figures 8.25, 8.26, 8.27, and 8.28 are scatter plots of the final examination results plotted against the tutorial and laboratory marks for the population of students that completed the questionnaire. The scatter plots are created with markers set by age, sex, number of years and language spoken respectively. Each of the plots shows a fairly strong positive relationship between the two variables, indicating that students who performed well in the final examination also did well during semester in the weekly tutorial and laboratory sessions.
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Figure 8.25: Scatter plot of final examination versus tutorial and laboratory marks for the population of students that completed the questionnaire with markers set by age

Figure 8.26: Scatter plot of final examination versus tutorial and laboratory marks for the population of students that completed the questionnaire with markers set by sex
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Figure 8.27: Scatter plot of final examination versus tutorial and laboratory marks for the population of students that completed the questionnaire with markers set by number of years in Australia

Figure 8.28: Scatter plot of final examination versus tutorial and laboratory marks for the population of students that completed the questionnaire with markers set by language spoken
A multivariate test using the general linear model was performed using `exam` and `tute_lab` as dependent variables and age, sex, number of years, and language spoken as fixed factors (see Table 8.11 for output). The analysis showed that age and years are statistically significant ($p = 0.003$ and $p = 0.005$ respectively). There were no significant differences between male and female students or between the four language groups.

### Table 8.12: Multivariate test for `exam` and `tute_lab` using age, sex, number of years and language spoken as fixed factors for the population of students that completed the questionnaire

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillai's Trace</th>
<th>Wilks' Lambda</th>
<th>Hotelling's Trace</th>
<th>Roy's Largest Root</th>
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</table>

The high school leavers performed better in both the final examination and during semester in the weekly tutorial and laboratory sessions ($\text{mean}_{\text{exam}} = 66$ and $\text{mean}_{\text{tute} \& \text{lab}} = 67$) compared with the mature age students (see Table 8.12a-b).
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Table 8.13a-b: Estimated marginal means for exam and tute_lab marks by age and sex respectively

1. AGE

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Age</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>EXAM</td>
<td>high school students</td>
<td>66.457</td>
<td>2.503</td>
<td>61.531</td>
</tr>
<tr>
<td></td>
<td>mature age students</td>
<td>56.251</td>
<td>3.144</td>
<td>50.064</td>
</tr>
<tr>
<td>TUTE LAB</td>
<td>high school students</td>
<td>67.313</td>
<td>1.382</td>
<td>64.593</td>
</tr>
<tr>
<td></td>
<td>mature age students</td>
<td>63.813</td>
<td>1.736</td>
<td>60.397</td>
</tr>
</tbody>
</table>

2. SEX

<table>
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<th>Dependent Variable</th>
<th>Sex</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td>Lower Bound</td>
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<tr>
<td>EXAM</td>
<td>male</td>
<td>61.524</td>
<td>1.881</td>
<td>57.823</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>61.184</td>
<td>3.826</td>
<td>53.656</td>
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<tr>
<td>TUTE实验室</td>
<td>male</td>
<td>65.879</td>
<td>1.038</td>
<td>63.836</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>65.247</td>
<td>2.112</td>
<td>61.090</td>
</tr>
</tbody>
</table>

In regard to the number of years spent in Australia (Table 8.13a), the results were interesting and unexpected. Recent immigrants (i.e. students who had spent 5 years or less in Australia) performed better in both the final examination and during the tutorial and laboratory sessions (mean exam = 67 and mean tute & lab = 56) compared with the Australian residents, with an average difference of 11 marks in the final examination between the two groups.

With respect to language spoken at home, the group means were not statistically significant (see Table 8.13b), although it is interesting to note that students from an Asian and Indian background preformed best in the final examination (mean exam = 66), while students from a European background scored the highest in the weekly tutorials and laboratory sessions (mean tute & lab = 68).
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Table 8.14a-b: Estimated marginal means for exam and late_lab by number of years and language spoken respectively

<table>
<thead>
<tr>
<th>Deendent Variable</th>
<th>YEARS</th>
<th>Mean</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXAM</td>
<td>recent immigrants</td>
<td>66.752</td>
<td>3.256</td>
<td>60.344</td>
<td>73.161</td>
</tr>
<tr>
<td></td>
<td>Australian residents</td>
<td>55.956</td>
<td>2.450</td>
<td>51.134</td>
<td>60.778</td>
</tr>
<tr>
<td>TUTE_LAB</td>
<td>recent immigrants</td>
<td>66.565</td>
<td>1.798</td>
<td>63.028</td>
<td>70.103</td>
</tr>
<tr>
<td></td>
<td>Australian residents</td>
<td>64.560</td>
<td>1.353</td>
<td>61.898</td>
<td>67.223</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deendent Variable</th>
<th>LANGUAGE</th>
<th>Mean</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXAM</td>
<td>English speakers</td>
<td>60.375</td>
<td>2.878</td>
<td>54.712</td>
<td>66.037</td>
</tr>
<tr>
<td></td>
<td>Middle Eastern</td>
<td>60.773</td>
<td>4.260</td>
<td>52.390</td>
<td>69.155</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>66.180</td>
<td>2.359</td>
<td>61.537</td>
<td>70.823</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>58.090</td>
<td>4.180</td>
<td>49.863</td>
<td>66.316</td>
</tr>
<tr>
<td>TUTE_LAB</td>
<td>English speakers</td>
<td>65.352</td>
<td>1.589</td>
<td>62.225</td>
<td>68.478</td>
</tr>
<tr>
<td></td>
<td>Middle Eastern</td>
<td>63.677</td>
<td>2.352</td>
<td>59.049</td>
<td>68.304</td>
</tr>
<tr>
<td></td>
<td>Asian &amp; Indian</td>
<td>65.434</td>
<td>1.303</td>
<td>62.871</td>
<td>67.998</td>
</tr>
<tr>
<td></td>
<td>European</td>
<td>67.789</td>
<td>2.308</td>
<td>63.248</td>
<td>72.331</td>
</tr>
</tbody>
</table>

8.6 Analysis of findings concerning students' attitudes towards assessment of group-work

An analysis of the number (and percentage) of responses for instance where the mean scores for the negative dimension was greater (or less) than the mean scores for the grprocess dimension. Table 8.14 shows that both high-schoolleavers (79%) and mature age students (77%) expressed more concerns about the negative aspects of being assessed as a group.

In addition, mature age students place a greater emphasis on the negative aspects than did the high-schoolleavers. In the gender category (see Table 8.15), both male (233 out of 304 males) and female students (30 out of 38 females) were of the opinion that there were many negative aspects regarding the assessment of group work.
CHAPTER EIGHT: STUDY IV-ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Table 8.15: Data summary statistics by age

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>%</th>
<th>negative &gt; group processes</th>
<th>group process &gt; negative aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>High-school leavers (1)</td>
<td>269</td>
<td>88</td>
<td>213</td>
<td>79</td>
</tr>
<tr>
<td>Mature-age students (2)</td>
<td>65</td>
<td>11</td>
<td>50</td>
<td>77</td>
</tr>
</tbody>
</table>

Table 8.16: Data summary statistics by sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>N</th>
<th>%</th>
<th>negative &gt; group processes</th>
<th>group process &gt; negative aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Male (1)</td>
<td>304</td>
<td>78</td>
<td>233</td>
<td>77</td>
</tr>
<tr>
<td>Female (2)</td>
<td>38</td>
<td>19</td>
<td>30</td>
<td>79</td>
</tr>
</tbody>
</table>

In relation to the number of years students had spent in Australia (Table 8.16), a far greater number of recent immigrants voiced their concerns about the problems encountered during the assessment of group work (87%); students who had spent 6 years or more in Australia indicated similarly (77%). Finally, in relation to students’ language background, the results were quite interesting (see Table 8.17). There was very little difference between students of English speaking background (73%) and Europeans (72%) in relation to concerns about the assessment of group work. Students of Asian and Indian background came at the top (86%).

Table 8.17: Data summary statistics by number of years in Australia

<table>
<thead>
<tr>
<th>Number of Years</th>
<th>N</th>
<th>%</th>
<th>negative &gt; group processes</th>
<th>group process &gt; negative aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Recent Immigrants (1)</td>
<td>61</td>
<td>18</td>
<td>53</td>
<td>87</td>
</tr>
<tr>
<td>Australian Residents (2)</td>
<td>277</td>
<td>81</td>
<td>214</td>
<td>77</td>
</tr>
</tbody>
</table>
CHAPTER EIGHT: STUDY IV-ATTITUDES TOWARDS GROUP-BASED ASSESSMENT

Table 8.18: Data summary statistics by language spoken

<table>
<thead>
<tr>
<th>Language Spoken</th>
<th>N</th>
<th>%</th>
<th>negative&gt; group processes</th>
<th>group process&gt; negative aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>English (1)</td>
<td>131</td>
<td>38</td>
<td>95</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Middle Eastern (2)</td>
<td>32</td>
<td>9</td>
<td>22</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Asian (3)</td>
<td>146</td>
<td>42</td>
<td>126</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>European (4)</td>
<td>32</td>
<td>9</td>
<td>23</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

Assessment is a big concern for students and this data shows it. Across all the four demographic variables, we can see that, irrespective of gender, age, cultural background or length of stay in Australia, students feel strongly about the negative aspects associated with the assessment of group work. As stated earlier on in the thesis, an important factor of this is the way the task is structured and assessed. Therefore, care needs to be taken in the way a task is structured, the objectives of the task, and the method of assessment.

8.7 Synopsis of chapter

The chapter set out to convey the message about the importance of small-group collaboration in instruction and the emphasis that needs to be placed on authentic assessment that closely links assessment with instruction. For instance, what students can accomplish in teams is important to those potential employers who are increasingly using work teams to respond to global competition (Hackman, 1990). Assessing students in groups provides information about group productivity and group effectiveness that individual assessment of student skills does not necessarily provide.

Group assessment makes it possible to measure students' ability to interact and collaborate with others. It also looked at the attitudinal questionnaire and investigated the effects of age, gender, length of stay in Australia and language spoken on student' attitudes towards the assessment of group work. An analysis of students' performance in the final examination as well as in the tutorial and laboratory session through semester
was undertaken. There were different cohorts of students for this part of the investigation - cohort 1: students that were interviewed \((n = 20)\), cohort 2: students that completed the questionnaire \((n = 344)\) and cohort 3: students enrolled in the subject \((n = 413)\).

The predominant purpose of assessment improvement is to enhance student achievement in critical thinking, problem solving, and good writing and communication skills. This study has indicated that there are problems when assessing collaborative group-based work as seen with comments made by the students that were interviewed. It is possible to carry out group-based assessment in an educationally sound way, but some care is needed to justify clearly both the purpose of a group task and the use of that task for assessment. Moreover, when group work is to be assessed, the method needs to be explained to students in a clear and unambiguous manner. Students will require some training or practice in relevant skills.

In terms of the attitudinal questionnaire, there was a slight difference in the average scores with the mean score for the anxiety dimension being 3.6 while the mean score for the grprocess dimension being 3.3. This can imply that students' placed a higher emphasis on the negative aspects of assessing group work than the group processes involved. However, it is important to remember that only three out of the fifteen questionnaire items came under the group process dimension. The multivariate tests showed a slight significant result for the four language groups \((p\text{-value} = 0.09)\). There was a 0.2 difference in the marginal means between native English speakers (3.5) and European students (3.3) in relation to the negative aspects about group-based assessment. There was also a 0.2 difference in marginal means in relation to the group process aspect of assessing group work but it was between Asian and Indian students (3.2), and Middle Eastern students (mean = 3.4).

Studying students' performance in the subject, we firstly take a look at cohort 1. For this cohort, students scored 67% in the final examination and 63% for the tutorial and laboratory sessions. Looking at cohort 2, students scored 63% in the final examination and 66% for the tutorial and laboratory sessions. If we look at cohort 3, we took all students enrolled in the subject into account. Students scored 59% in the final
examination and 63% for the tutorial and laboratory sessions. This indicates that across the three cohorts, the final examination and tutorial session results were pretty much similar. Scatter plots of the final examination versus the tutorial and laboratory session results revealed positive trends indicating that students who performed well in the final examination also did well during semester in the weekly tutorial and laboratory sessions. This was true across the four variables, namely, age, gender, length of stay in Australia and language spoken.

Multivariate analysis was also performed with cohort I group of students. There were significant differences for language spoken (p-value = 0.009) only. Native English speakers scored 57% in the final examination while European students scored 91% in the final examination. For the tutorial and laboratory work, Asian and Indian students scored the lowest (63%) in comparison to the European students (75%). This was anticipated results because students from an Asian background had difficulty with comprehension of questions set out in the tutorials. For cohort 2, there were significant statistical differences for age (p-value = 0.003) and length of stay in Australia (p-value = 0.005), which was interesting.

Language diversity did not come out as significant this time. High school students performed better (66%) in the final examination than the mature age students (56%). Australian residents performed poorly (56%) in the final examination compared with the recent immigrant students (67%), which was an unexpected result because it was expected that students who had been in the country for a few years and who had been through some form of education under the Australian system would have scored better (and higher) than students who had recently migrated.

In summary, the findings were uniform across all the four demographic groups and are listed below:

a. Both high-school students and mature-age students were concerned more about the negative aspects of group assessment.

b. Both male and female students also had concerns about the negative aspects of group assessment, despite a smaller female representation overall compared to males.
c. A greater proportion of recent immigrants expressed concern about the negative aspects of the assessment of group work.
d. Finally, while students from all four language groups were concerned about the negative aspects of group assessment, a larger proportion of students of Asian and Indian descent held this opinion.

There is a great deal of benefit to be gained from group work, for both staff and students alike. From the lecturer's point of view it can promote a variety of transferable skills and, depending on how the work is assessed, it is possible to enhance the learning process too. On a purely pragmatic level it may also be possible to save time spent on assessing students' work. From the students' point of view, engaging in group work offers a range of benefits and the assessment process can be an interactive part of the learning process. The major gains in transferable skills are in the areas of oral communication, negotiation and interpersonal skills. Working in a group can also promote the sharing of ideas and problem solving skills, as the student might feel less intimidated and more willing to discuss work with their peers.

Whilst the assessment of group work can also play a major part in the learning process, it is often this aspect of group activities which most concerns many academics and students as well. What is important is that the assessment methods and criteria are made clear to students before they begin the activity. Academics have to decide whether they are prepared to give each student the same mark for the group outcome or whether they feel more comfortable embedding some means of generating an individual mark. The group mark approach more closely mirrors the world of work, where scientists working in teams generally all share in the success or failure of a project. If students are aware of this before the activity begins then they must be made aware that it is up to them to ensure that all group members contribute to the activity.

Team effectiveness involves many dynamic processes, for instance, coordination, communication, conflict resolution, decision making, problem solving, and negotiation (Salas et al., 1992). If teachers observe students collaborating with others, then it makes it possible to evaluate their ability to work with others and their ability to monitor and shape their own behaviour (Redding, 1992). Complex problems may be too intimidating
for students to work on alone but may be better accomplished if they can work with others. The drive toward authentic assessment calls for complex problems in realistic contexts (Meyer, 1992) with careful care and thought put towards the wording of questions. As group work is successful in developing a range of skills as well as discipline specific skills and knowledge, both staff and students must be clear what is being assessed by a given method. There are many assessment methods suitable for assessing group work. They may be used individually or in combination in order to assess a range of skills and knowledge and to generate a group or individual mark.
Chapter 9

Implications of findings, directions for future research and concluding remarks

9.1 Introduction

This chapter will summarise the findings from the study and discuss the implications of the findings obtained from both the quantitative and qualitative aspects of the investigation. In general, the findings of the investigation confirm and extend the results found in the literature. The main purpose of this project was to investigate the effects of group work on students' motivational and achievement levels in a large first-year undergraduate mathematics subject in both face-to-face and computer supported environments. Few studies have been conducted specific to the area of Australian tertiary mathematics comparing traditional instruction with computer supported collaborative learning (CSCL) instruction. Consequently, this project was conceived in response to the absence of qualitative and quantitative data in this domain.

This chapter is reflective in nature. Important themes are taken up from both the literature review and theoretical framework and followed through to the results of the studies. Implications for the practices of teaching and learning are discussed. To conclude, directions for future research are proposed.
9.2 Results from the four studies

9.2.1 Synopsis of results and findings from study I

Study I looked at the data on students' preferences for learning and the effects of age, gender, language background and length of stay in Australia on students' preferences. The difference in the mean scores were not statistically significant with the mean score for the collaborative learning style preference being 3.4 and the mean score for the individual learning style preference being 3.3. The scatter plots of the two dimensions plotted against each other with markers set by each of the four variables of interest displayed a negative trend. This indicates that there is a negative relationship between students' preference for either collaborative learning or individual leaning. The trend appears to show that higher the score on the collaborative learning style dimension, lower the score on the individual learning style dimension, especially among the four language groups, where European language background students appeared to favour collaborative learning as opposed to the Middle Eastern background students.

The multivariate analysis of variance (MANOVA) produced statistically significant results for language spoken at home (p-value = 0.053). The marginal means for the two dimensions showed that Middle Eastern language background students had a stronger preference for working alone (mean = 3.5). European, Asian and Indian students showed a greater preference for working together with other people (mean = 3.4). This result was quite surprising because it was expected the Asian and Indian students would also prefer to work individually. It is difficult to pinpoint a reason for this finding, as the model investigated the interaction between the variables and so these students had also been to school in Australia so had similar school backgrounds to the other language groups. It may point to a cultural heritage that values authority and therefore the students have a teacher-centered preference for learning.

There were no significant differences in students' preferred learning style across the two age groups — high school leavers and mature age students, or across gender or migrant/international status. In relation to age, of the 65 mature age students, 58% indicated that they preferred to work individually, though this was not statistically
significant. High-school students showed no statistically significant preference for either individual or collaborative learning styles.

In relation to gender, of the 38 females that participated in the study, 61% indicated a stronger preference for collaborative learning. Although this result is not statistically significant, the finding supports previous literature in that females favour collaborative learning methods. While there have certainly been gains made in gender equity in Australian higher education, and there have been some increases in women's participation in non-traditional areas, an analysis of the most recent student enrolment data shows that gender equity in the Australian higher education is yet to be achieved (Carrington & Pratt, 2003).

Changing the perception of learning in engineering is important. Individual, hard or technical approaches to learning mathematics may not be attractive to women or indeed many men for that matter. Changing the perception of learning mathematics may encourage more women to consider engineering, but practical support such as access to equity scholarships for women of low SES backgrounds will be needed. Indeed, UTS is introducing alternate entry for women into Engineering from 2006 with extra support for these students.

### 9.2.2 Synopsis of results and findings from study II

Study II has looked at the data on students’ views about group work and what they consider to be the objectives for setting group work in mathematics. The effects of age, gender, language background and length of stay in Australia have been investigated. The results were obtained from both a qualitative and quantitative study. The student quotes that supplemented literature indicated that collaborative learning has an overall positive effect in the cognitive domain as, well as the social and affective domain in tertiary mathematics.

The mean scores were not statistically significant with the average score for the skills-based objectives being 2.4 and the average score for the conceptual-based objectives being 2.4 as well. The scatter plots of the two dimensions plotted against each other with markers set by each of the four variables of interest displayed a positive trend. This
indicates that there is a positive relationship between students' views about conceptual-based and skills-based objectives. The trend shows that students rated both sets of objectives as equally important and relevant. The multivariate analysis of variance (MANGVA) produced no statistically significant results for any of the four variables - age, sex, length of stay in Australia and language spoken at home.

The marginal means for the two dimensions across the four demographic variables were not statistically different. This indicates that there was no difference in what male or female students; high-school leavers or mature age students; recent immigrants or Australian residents; Native and non-Native English speaking students considered to be the objectives for setting group work. In other words, they considered the objectives to all be equally important and relevant.

A different analysis was also done in regard to the number of instances where the mean score for the skills-based dimension was greater (or less) than the mean score for the conceptual-based dimension. The results were tabulated in Tables 6.9-6.12 and sorted by the four variables of interest. Zariski and Davis (1997) asked their students which were the three most relevant objectives to them and they chose cooperation (item 1), conflict resolution skills (item 7) and organising skills (item 3). All these three objectives fall under the skills-based objectives dimension. This question was not put to students in my study but the results from the analysis done in section 6.4 are nevertheless interesting.

The analysis showed that there were no statistically significant differences across the two age groups or between recent immigrants and Australian residents. However, looking at gender, of the 38 female students in the sample, 63% indicated skills-based objectives as being more relevant to them than the conceptual-based objectives. Male students appeared to place equal importance on both types of objectives. Looking at language/cultural diversity, the results were not statistically significant (if compared with the MANGVA results), but it is interesting to note that in the Asian and Middle Eastern language groups we find a disparity in opinion. 56% of the Middle Eastern students \((n = 32)\) considered conceptual-based objectives to be more important and
relevant while 59% of the Asian students (n = 146) considered skills-based objectives to be more important and relevant.

There is no doubt that implementing collaborative learning is a structured but complex process. It must be noted that much of the research on collaborative learning has proposed that the benefits are usually long term rather than having an instant effect. Examination marks may not increase immediately but using properly structured group work early in a degree course can help the students to reflect more on their work. This can only be of benefit in later subjects that build upon the foundation courses.

Changes in teaching and learning styles are not a quick and easy matter. Change is a gradual process that involves both trying out new strategies and techniques as well as carefully considering the goals for which those practices are intended. Instructors are currently faced with a variety of challenges like large class size, diverse student populations, management problems, accountability pressures, legal issues, curriculum changes and new technology as well as age, cultural and language diversity. The use of collaborative learning strategies in mathematics can make classroom life for instructors and students more supportive, appealing, engaging, intellectually stimulating, creative, interesting, mathematically productive and fun.

9.2.3 Synopsis of results and findings from study III

Study III has looked at the data on students’ views about using computers, in particular CAS such as Mathematica. The effects of age, gender, language background and length of stay in Australia have been investigated. The results were obtained from both a qualitative and quantitative study. The student quotes revealed hierarchical themes regarding the use of computers in mathematics instruction – a lower level theme where students viewed Mathematica as a sophisticated number cruncher and a second higher level theme where students were of the opinion that Mathematica not only could be used as a sophisticated number cruncher but also to help in their understanding of concepts. Arguments for and against use of CAS in the literature are many, most of them pedagogical but also some practical (Coupland, 2000; Cretchley, 2001). This study has shown the desirable effects of using Mathematica which supports the findings of many
existing research studies, but not so many of these are conducted in the engineering education domain where mathematics is a service subject.

There are many inferences that can be drawn regarding using computers in the teaching and learning of mathematics at university. As students in this study pointed out, it is very exciting, enjoyable and productive to use computers in class. Some of the students are keen to use computers, so the environment becomes more conducive for learning. Due to this, students' natural curiosity can be utilised to its fullest potential because they are keen to explore and discover. Sound social relationships develop as they discuss their findings amongst each other. They take a certain degree of responsibility for their own learning.

The mean scores were slightly significant with the average score for the anxiety dimension being 3.5 and the average score for the benefits dimension being 4.9. The scatter plots of the two dimensions plotted against each other with markers set by each of the four variables of interest displayed a negative trend. This indicates that there is a negative relationship between students' views about using computers, that is, there is a negative relationship between anxiety and benefits. The trend shows that students rated the benefits of using computers more highly than they did with the drawbacks of using computers. The multivariate analysis of variance (MANOVA) produced statistically significant results for gender (p-value = 0.01) and language spoken at home (p-value = 0.02). There was a 0.2 difference in the marginal means for the anxiety dimension with females indicating greater anxiety than males.

Looking at language/cultural diversity, the results were interesting. There was a 0.6 difference in students' opinions. Middle Eastern students displayed the highest level of anxiety (mean = 3.9) while European students displayed the least (mean = 3.3). Native English speakers highly favoured the use of computers through their scoring on the benefits of using computers (mean = 4.9) in comparison to their Middle Eastern counterparts (mean = 4.2). A different analysis was also done in regards to the number of instances where the mean score for the anxiety dimension was greater (or less) than the mean score for the benefits dimension. The results were tabulated in Tables 7.6-7.9 and sorted by the four variables of interest. Across all the four variables, the number
(and percentage) of responses that appeared to favour the benefits of using computers was greater than that of the drawbacks in relation to anxiety.

Change can produce stress and, unless acknowledged and managed appropriately, it can inhibit the learning process and subsequent success of the innovation. The change required will be greatest where it conflicts with students' previous educational experiences and current conceptions of learning. This study has shown that some students, in particular female students and Middle Eastern students, have high anxiety about the use of computers in their learning of mathematics (from the multivariate analysis). This should be acknowledged in teaching and learning, and support offered to alleviate the anxiety.

This study suggests that if students are to use CAS, it is important that it be blended into their everyday class work. They must therefore be introduced to CAS in a systematic way, and they need to be required to use it. Computer algebra systems (CAS) such as Mathematica, challenge the traditional mathematics curriculum, causing many questions to arise. For instance, what will be the place of memorising algorithms in the future? Will we as academics still require students to be able to 'integrate by parts' using pen-and-paper techniques? Can we broaden the mathematics curriculum to include more generic skills such as mathematical modelling if we allow CAS to perform the algebra and calculus manipulations? Also, the role of assessment will change in the future mathematics curriculum. These are just a few of the issues that mathematics education researchers have to consider.

9.2.4 Synopsis of results and findings from study IV

Study IV set out to investigate small-group collaboration in instruction and the emphasis that needs to be placed on authentic assessment that closely links assessment with instruction. For instance, what students can accomplish in teams is important to those potential employers who are increasingly using work teams to respond to global competition (Hackman, 1990). Assessing students in groups provides information about group productivity and group effectiveness that individual assessment of student skills does not necessarily provide.
It also examined the attitudinal questionnaire and investigated the effects of age, length of stay in Australia and language spoken on student' attitudes towards the assessment of group work. An analysis of student's performance in the final examination as well as in the tutorial and laboratory session through semester was undertaken. There were different cohorts of students for this part of the investigation - cohort 1: students that were interviewed \((n = 20)\), cohort 2: students that completed the questionnaire \((n = 344)\) and cohort 3: students who sat the final examination \((n = 436)\).

The predominant purpose of assessment improvement is to enhance student achievement in critical thinking, problem solving, and good writing and communication skills. This study has indicated that there are problems when assessing collaborative group-based work as seen with comments made by the students that were interviewed. It is possible to carry out group-based assessment in an educationally sound way, but some care is needed to clearly justify both the purpose of a group task and the use of that task for assessment. Moreover, when group work is to be assessed, the method needs to be explained to students in a clear and unambiguous manner. Students will require some training or practice in relevant skills.

For the attitudinal questionnaire, the students placed a higher emphasis on the negative aspects of assessing group work than the group processes involved. However, it is important to remember that only three out of the fifteen questionnaire items came under the group process dimension. The multivariate tests showed a slight significant result for the four language groups \((p\text{-value} = 0.09)\). There was a 0.2 difference in the marginal means between native English speakers \((3.5)\) and European students \((3.3)\) in relation to the negative aspects about group-based assessment. There was also a 0.2 difference in marginal means in relation to the group process aspect of assessing group work but it was between Asian and Indian students \((3.2)\), and Middle Eastern students \((\text{mean} = 3.4)\).

Studying students' performance in the subject, we firstly take a look at cohort 1. For this cohort, students scored 67% in the final examination and 63% for the tutorial and laboratory sessions. Looking at cohort 2, students scored 63% in the final examination and 66% for the tutorial and laboratory sessions. If we look at cohort 3, we took all
students enrolled in the subject into account. Students scored 59% in the final examination and 63% for the tutorial and laboratory sessions. This indicates that across the three cohorts, the final examination and tutorial session results were pretty much similar. Scatter plots of the final examination versus the tutorial and laboratory session results revealed positive trends indicating that students who performed well in the final examination also did well during semester in the weekly tutorial and laboratory sessions. This was true across the four variables, namely, age, gender, length of stay in Australia and language spoken.

Multivariate analysis was also performed with cohort 1 group of students. There were significant differences for language spoken (p-value = 0.009) only. Native English speakers scored 57% in the final examination while European language background students scored 91% in the final examination. For the tutorial and laboratory work, Asian and Indian language background students scored the lowest (63%) in comparison to the European language students (75%). This was anticipated results because students from an Asian language background had more difficulty with comprehension of questions set out in the tutorials. For cohort 2, there were significant statistical differences for age (p-value = 0.003) and length of stay in Australia (p-value = 0.005) which was interesting. Language diversity did not come out as significant this time.

High school students performed better (66%) in the final examination than the mature age students (56%). Australian residents performed poorly (56%) in the final examination compared with students who had arrived in Australia in the past 5 years (67%). These include international students. It is possible that the entry requirements for these students are more stringent than the local students.

There is a great deal of benefit to be gained from group work, for both staff and students alike. From the lecturer's point of view it promote a variety of transferable skills and, depending on how the work is assessed, it is possible to enhance the learning process too. On a purely pragmatic level, it may also be possible to save time spent on assessing students' work. From the students' point of view, engaging in group work offers a range of benefits and the assessment process can be an interactive part of the learning process. The major gains in transferable skills are in the areas of oral
communication, negotiation and interpersonal skills. Working in a group can also promote the sharing of ideas and problem solving skills, as the student might feel less intimidated and more willing to discuss work with their peers.

Whilst the assessment of group work can also play a major part in the learning process, it is often this aspect of group activities which most concerns many academics (and students as well). What is important is that the assessment methods and criteria are made clear to students before they begin the activity. Academics have to decide whether they are prepared to give each student the same mark for the group outcome or whether they feel more comfortable embedding some means of generating an individual mark. The group mark approach more closely mirrors the world of work, where scientists working in teams generally all share in the success or failure of a project. If students are aware of this before the activity begins then they must be made aware that it is up to them to ensure that all group members contribute to the activity.

Team effectiveness involves many dynamic processes, for instance, coordination, communication, conflict resolution, decision making, problem solving, and negotiation (Salas et al., 1992). If teachers observe students collaborating with others, then it makes it possible to evaluate their ability to work with others and their ability to monitor and shape their own behaviour (Redding, 1992). Complex problems may be too intimidating for students to work on alone but may be better accomplished if they can work with others.

The drive toward authentic assessment calls for complex problems in realistic contexts (Meyer, 1992) with careful care and thought put towards the wording of questions. As group work is successful in developing a range of skills as well as discipline specific skills and knowledge, both staff and students must be clear what is being assessed by a given method. There are many assessment methods suitable for assessing group work. They may be used individually or in combination in order to assess a range of skills and knowledge and to generate a group or individual mark.
9.3 Implications for the use of collaborative learning

The views of many students in this project point toward the fact that they found the collaborative activities interesting and enjoyable, and a significant number of students agreed with the statement that they thought the collaborative activities improved their mathematical understanding. It must be noted that some students did not agree with these statements, with some students expressing an extreme dislike for collaborative learning methods. A variety of learning and teaching strategies is thus called for, to best meet the needs of all students. It was also seen that collaborative groups do not always function effectively for a variety of different reasons, and instructors employing collaborative learning methods need to pay constant attention to minimising factors that contribute to such ineffectiveness, and addressing problems where they occur.

The most comprehensive conclusion that can be reached from this project is in the area of individual student preferences for different styles of learning. The proportion of students selecting a collaborative style of learning as their preferred choice – compared to the other learning style preferences – was interesting but not statistically significant. This finding suggests that the standard delivery of class lessons is not catering for the needs and/or preferences of the some students. This does not mean that we should change unilaterally or exclusively to collaborative learning methods, but there is an indication that we should include some opportunities within mathematics classes for students to work collaboratively, and talk about mathematics.

This project has also identified further implications for instructors wishing to implement collaborative learning methods in their teaching, such as resourcing, the preparation of suitable activities or tasks, and the training of staff who may be unfamiliar with either the technology or collaborative learning methods. While the mathematics problems do not necessarily have to be specifically designed for group work, they do need to be at an appropriate level, and preferably not easily divided up among group members.
9.4 Implications for incorporating Mathematica and other technology tools

Incorporating technology into the mathematics subject was a complex issue and this project has only started to unravel some of its implications. The key to understanding it is to remember that computer algebra systems and their use are seen differently, from different perspectives, by all the participants. Mathematica offers powerful support for learning skills through inquiry and problem solving. It can promote student exploration through collaborative involvement in authentic, challenging multidisciplinary tasks by providing realistic complex environments for student inquiry, furnishing information and tools to support investigation, linking classrooms for joint investigations, and presenting data in ways that support mathematical thinking and problem solving (Means et al., 1993).

Instructors can draw on technology applications to simulate real-world environments and create actual environments for experimentation, so that students can carry out authentic tasks and use a variety of tools to gather information and solve problems. Working on 'authentic tasks', which Brown et al. (1989) define simply as the ordinary practices of the culture, engages students in sustained exploration and provides multiple opportunities to reflect on the decisions made in trying to address the problem. Authentic tasks can be highly motivating for students, leading them to acquire advanced skills and knowledge because they become engrossed in the problems that, for example, navigators, anthropologists, or historians face.

Mathematica can be used to enable students to investigate questions through technology applications accessible to students, which allow them to gather information (CD-ROM); to store, organise, and analyse information; and to represent and convey to others what they have learned (multimedia applications, desktop publishing, graphics programs). These technologies are primarily general-purpose tools. The essence of the innovation lies in the development of an instructional framework within which these tools are used. Students can work individually or in collaboration with others in these inquiry-oriented curriculum units, and work over extended periods of time on projects culminating in presentations that provide the basis for assessing their learning.
However, all this is not possible without adequate resources, such as professional development and training. Without adequate training of staff in using computer technology, on-going technological and pedagogical support, implementation of computer-supported instruction in tertiary mathematics is going to continue to be a challenge for both students and teachers.

If instructors are not going to receive the support they require to implement technology in their classrooms, they are less likely to make the effort to learn the software to be able to teach it. Not many teachers have 'spare' time on their hands during which they could learn how to use new software. All this in turn affects students who are not going to, or want to, change their mathematics learning styles if they do not receive adequate explanations and demonstrations. So we end up with this vicious cycle and this cycle needs to be broken sooner than later.

Love (1995) points out that the usual school mathematics curriculum consists of learning to carry out techniques, rather than using them. When techniques are automated, what role is there for school mathematics? This question must now be posed for much of undergraduate mathematics as well. Here is an opportunity to turn attention to the uses of mathematics, but not just the uses of mathematics (which are now automated), but the whole set of meta-techniques used by professional users of mathematics when they engage in problem solving and modeling (Coupland, 2004).

In a face-to-face environment and also a computer-supported environment, it is possible that pressure on tertiary mathematics academics from the wider community to supply graduates who are more skilled at problem solving than in carrying out routine calculations will eventually permeate to the first-year level. Another possibility is that pressure to change will come from university administrators concerned about decreasing enrollments in mathematics courses. Students send a pretty clear message when they leave or decline to enroll in courses that are perceived to be irrelevant to real life.

A large study by Forgasz and Leder (2000) found that there were sharp differences between five universities in Australia when students were asked about the teaching and learning climate in mathematics. This indicates that the immediate learning context of
CHAPTER NINE: IMPLICATIONS OF FINDINGS & CONCLUDING REMARKS

an institution can be changed for the better through attention to the issues identified by their research:

Students' suggestions for the need for better teachers and tutors, better course advice, more social contact within departments, a 'space of their own', and raising awareness of potential career paths are worthy of consideration

(Forgasz & Leder, 2000, p42)

Other concerns described by students in the research conducted by Forgasz and Leder (2000) included the need to make lectures more interesting, and to show the place of topics being studied within an overview of the current state of mathematics. These are areas where a good CAS demonstration in lectures would help.

### 9.5 Challenges for students

Learning with others is a stepping stone towards being a reflective learner focused on making personal meaning. It may however be the case that some aspects could involve relying on others, thereby becoming a dependent learner. As issue for future research is to unpick the relationship between an independent learner and being a learner who is focused on making personal meaning and growth.

All students rely to some degree on help from each other as well as from their lecturers and tutors. Therefore, recommendations for teaching must include provision for students to discuss things together and have access to skilled tutors. The tutors should be skilled in the CAS but also in promoting group work. Examples of this kind of work can be found in research done by Guin and Trouche (1998). Goos et al., (2002) provide an example of research into the kinds of social interaction in small groups that facilitate successful problem solving.

Many academics have feared that students, especially so-called 'at-risk students', would become frustrated by the technical demands of the kinds of technologies described above. This has certainly been true in this research project, however, it is vital to emphasise that learning the technical aspects of computer applications is not a major
problem for most students. Students face several other kinds of challenges when they use computer-supported or face-to-face collaborative learning techniques to support them in active, inquiry learning. These include (1) understanding their responsibilities as active learners; (2) getting help with individual learning needs; and (3) integrating their technology-supported inquiry learning with their larger tertiary experience (Means et al., 1993).

9.5.1 Understanding their as active learners

Authentic inquiry tasks provide exciting new challenges for students and can also require a host of advanced intellectual and social learning skills, involving new levels of independence (Means et al., 1993). In this project, students' difficulties with conjecturing with Mathematica were sharp. Some students needed step-by-step guidance when familiarising themselves with a new procedure for generating questions, gathering information, or carrying out a cooperative task; others, and most students over time, needed a reminder of the 'big picture'. They needed considerable discussion in the early stages of a new activity, less when their investigation was well under way.

9.5.2 Getting help with individual learning needs

Although the kinds of inquiry learning Mathematica fosters is appropriate for most students, many students need special support to manage the social and intellectual challenges of posing and exploring their own questions and in sustaining attention and involvement in long-term projects. This investigation along with other research points to the subtle variation in the learning strengths and needs students bring to computer-supported inquiry learning. They point to the challenge for staff of assessing students' learning in a complex, simulated learning environment. There are multiple student learning outcomes at stake:

a. acquiring new information,
b. linking visual and print information, and
c. developing specialised computer skills for working with the software, cooperative abilities, reasoning and problem-solving abilities.
Clearly, staff need multiple assessment techniques and associated intervention strategies to meet varied student needs (Means et al., 1993). Within the classroom, close monitoring of students' learning can enable all students to benefit from reform-oriented learning activities. Beyond the classroom, particularly when in transition from traditional approaches to more inquiry-oriented approaches, students may need help in making sense of the differences in their experiences and their teachers' expectations across their learning settings.

9.5.3 Integrating computer supported inquiry learning

Many students' first experience with computer-supported inquiry learning is an isolated one - a new program, or a teacher's experimentation. Until higher education reform makes this a more pervasive learning environment for mathematics students, they may experience a discrepancy between their inquiry-learning experiences and the emphasis on factual memorisation in other subjects. In this project, students experienced this dissonance and isolation in comments like, "It feels so strange", "Why do we have to do this?" When discrepancies in philosophy and approach across classrooms are made explicit, particularly at the undergraduate level, students are more able to adapt to these discrepancies. Their resulting awareness of the ways they are learning can help them to generalise new inquiry skills to new, appropriate situations.

9.6 Implications for mathematics education

As a result of this investigation, a number of implications for education, in general, and tertiary mathematics, in particular, arise. These findings, however, should be considered in light of the limited nature of the project:

1. This project highlights the need for adequate support and training for staff and students when implementing new techniques such as collaborative learning.
2. Collaborative learning without computers was quick and easy to implement and students could learn the mathematics almost immediately. However, the design of good collaborative materials is time-intensive and needs to be at an appropriate level.
3. Preference for different learning styles implies that changing teaching and learning methodologies to include computer-supported and/or face-to-face collaborative learning methods needs to be considered even if it may receive initial resistance from students as well as teachers.

4. The effects of gender difference, cultural diversity (based on language spoken at home) and length of stay in Australia, on attitude and approach to computers and collaborative learning in mathematics identifies the need for teachers to provide an environment that supports and encourages a diverse range of learners and their needs.

5. The use of software such as Mathematica requires time to learn. The package initially interferes with mathematics learning but over time, and with adequate technological and pedagogical support and training, implementation of technology into the mathematics classroom would receive less resistance from teachers and students.

6. Integration of technology into undergraduate mathematics, by modifying existing curricula, is a viable and effective foundation for current curriculum development. In the longer term, however, complete curriculum reform may be required on a wider tertiary level.

9.6.1 Implications for teaching and learning

The power of computer algebra systems and the use of collaborative learning methods given the enormous benefits of both instructional and learning methodologies is only tapped in a small way in tertiary mathematics education. A radical re-think of the structure of typical mathematics degree and service courses is needed to change this.

Much of the content of first year subjects is concerned with learning routine algorithms. If the content of years 11 and 12 at high school is also reconsidered then the possibility for a completely different syllabus at these levels is exciting to say the least. It could be based in real-world problem solving and involve rich learning tasks and problem-based learning. It could also include problem solving based on investigations of abstract mathematical topics. Such a curriculum would require innovative staff.

The availability of CAS on personal computers has the potential to give staff as well as students the experience of being researchers individually as well as with their peers. Other new developments in information technology such as chat rooms and well-
conducted email discussion lists where staff can pose mathematical questions without fear of ridicule, also add to possibility of learning collaboratively. An issue that needs to be addressed is the extent to which the automation of routine pen-and-paper procedures at the first-year is necessary for learning of more complex procedures and concepts at later levels. This is an important area for developmental research.

On the basis of analysis of interview transcripts and questionnaire responses, I was able to obtain clear directions for immediate improvement in the context of teaching and learning tertiary mathematics. These include:

- Ensuring that all tutors are adequately trained in working with computer algebra systems as well as in collaborative learning methods;
- Integrating CAS and group work into the teaching and learning process;
- Consideration of workload involved in learning a new software and learning how to work in groups;
- Consideration of assessment tasks in order to examine conceptual understanding;
- Helping students to find their own purpose in the task at hand by pointing out its relevance to their own mathematical studies and/or to future career directions;
- Providing assistance whereby expert users work alongside novices.

9.7 Implications for assessment

Educators and policy makers have invested confidence in formative, authentic assessments as a promising tool for tertiary education reform, the goal of which is to enhance students' development of critical thinking skills, writing and communication skills, multidisciplinary understanding, and social competencies.

Assessment reform in mathematics, which involves the shift from multiple-choice, nonreferenced tests (summative) toward performance-based (formative) assessments, is founded upon the assumption that the latter are more pedagogically valuable and more accurate reflections of student achievement than the former. In addition, many educators claim that performance assessments are more interesting for students, and
therefore, engage students in the assessment process (Office of Educational Research and Improvement, 1997).

Studies on formative assessment clearly point to the importance of regular student self-assessment as part of formative assessment. Self-assessment involves reflection on one’s learning strategies as well as analysis of one’s work. The implications are for a systematic approach by teachers underpinned by a belief by both teachers and students that the process of self-assessment helps learning (D’Souza & Wood, 2004).

What this investigation has shown is that there are problems with the assessment of group work. We need to determine how to be fair to the individual members of the group and recognise their individual contributions. Providing feedback is vital as it contributes to learning if students are helped to act upon it. This would mean focusing advice on tasks and the learning strategies used by students, using descriptive feedback that gives details of why answers are correct or wrong, consideration of the oral and/or written dimensions of feedback and how it could be tailored to individuals. Also, the drive towards more authentic, formative assessment calls for setting complex problems in realistic contexts. Complex problems may be less intimidating to students if they can work with others collaboratively. This would mean designing better materials than that which is currently available, materials that would foster understanding and self-reflection (D’Souza & Wood, 2004).

Whilst the assessment of group work can play a major part in the learning process, it is often this aspect of group activities which most concerns many academics and students alike. What is important is that the assessment methods and criteria are made clear to students before they begin the activity. Academics have to decide whether they are prepared to give each student the same mark for the group outcome or whether they feel more comfortable embedding some means of generating an individual mark. The group mark approach more closely mirrors the world of work, where people working in teams generally all share in the success or failure of a project. If students are aware of this before the activity begins then they must be made aware that it is up to them to ensure that all group members contribute to the activity.
CHAPTER NINE: IMPLICATIONS OF FINDINGS & CONCLUDING REMARKS

9.8 Review of the research process - a personal view

I have learnt a great deal about the practicalities of conducting research in the course of completing this project and there are a number of things I would do differently in future projects. Following an action research methodology, I have the opportunity to reflect on the action - the way in which this investigation was carried out, the method of data collection, the results obtained, the implications of the findings and any difficulties that arose along the way.

The main source of data for this research was questionnaires of university engineering students with voluntary participation. The return rate for such surveys was not very problematic because the questionnaires were administered during the tutorial class and students had to complete it within the hour. Alternative sources of information and incentives for participation would be considered in future work, for instance, incentives for participating in one-to-one and focus group interviews. Another possibility is online completion of questionnaires of shorter length at various points during a semester. The use of the Internet for capturing data is an exciting field and is being developed by many researchers (see for example, Crawford & Fitler, 2003 as identified in Coupland, 2004). With the questionnaire, a possible problem that deterred students resulting in the reason for the number returned incompletely included the length of the questionnaire which ran into a few pages.

After speaking with the lecturer and tutors concerned, administering the questionnaire in class time was much easier than simply distributing them in class time say, before a break, and returning later to collect them. For this project, I received 344 responses to the questionnaire out of a possible 436 students. This is a reasonably good result taking into consideration that Tabachnick and (1983) suggest that 100-200 is good enough for most purposes. However, they point out that larger sizes ensure more reliable correlation coefficients.

In the original design of the research project, two questionnaires were to be administered - one at the start of semester and the second towards the end of semester. This would have enabled some analysis of changes in responses over time, and the
collection of information about students' high school experiences could have been done as well. Due to timing and the need for ethics clearance in order to conduct the project, only one questionnaire was administered towards the end of semester.

I would also be more aware of critical variables from the beginning such as the computing background of students, and their experiences of working in groups or lack there of, and would also consider using a developed and tested questionnaire from some other source to collect relevant data. Ideally, a research project is completed in a shorter amount of time. I found that fitting this work around my teaching responsibilities and other commitments as well as personal hindrances meant that I had to redo parts of the analysis, a few times sometimes, in order to reacquaint myself with the results each time I returned to the work.

### 9.9 Reflections on the action research methodology adopted

Action research, as described in chapter four, is an iterative process where the practitioner plans, acts, observes and reflects which leads to a new cycle of planning. To remind ourselves of the iterative process, see Figure 9.1 below. Let us consider the various components of this study.

![Figure 9.1: Action research cycle](image-url)
9.9.1 **Blended learning styles**

*Reflection:* For this study, collaborative learning was introduced into the ten weekly tutorials and one assignment. The examination and class test were done individually, though many students worked in groups to prepare for these tests. This seems to be an appropriate mix between individual and collaborative learning.

*Plan:* Continue with the mix of teaching and learning styles.

9.9.2 **Students**

*Reflection:* This study shows that the students adapted quickly to collaborative learning in their tutorials. The positive outcomes for collaborative learning, as shown in the literature, were validated for this group. Due to the size of this cohort, these outcomes are generalisable to similar cohorts. One of the positive features was the attendance at tutorials which was significantly higher than previous years. Examination results were comparable with previous years. No group of students appeared to be disadvantaged by the move to collaborative learning. The study showed that students with non-English language backgrounds may have more difficulty with language questions.

*Plan:* Continue with collaborative learning in tutorials and assignments. Introduce language support for students with a first language other than English.

*Observe:* There is no need to repeat the detailed analysis of learning styles and the benefits of collaborative learning.

9.9.3 **Materials**

*Reflection:* The collaborative materials in the tutorials were designed using the TALC system (techniques, applications, language and concepts, adapted from Smith *et al.*, 1996). These worked well and alerted the students to different types of learning in mathematics. One drawback was that for a few tutorials the questions could be split up which enabled some students to specialise in one type of question rather than everyone working on the questions together.
Plan: Revision of the questions would enhance learning.

Observe: Check with tutors at the end of the semester to see if the changed materials worked well. Sit in on classes using new materials to observe the students' interactions.

### 9.9.4 Assessment

**Reflection:** Students were assessed individually as well as in a group. The final examination was assessed on individual merit, while the assignment and weekly tutorial tasks were assessed as a group. Students appeared to have no major issues with the group-based assessment in the way it was structured, that is, marks allocated for participation and attendance, and marks allocated for each question set.

**Plan:** Continue with the method of assessment adopted. Think about other forms of assessment such as peer assessment. Ensure that students understand the criteria for group product and processes; inform them how individual contributions to the group will be measured; and inform them how grades between individuals in the group will be allocated.

### 9.9.5 Tutors.

**Reflection:** This is where I was most surprised. The tutors were sessional academics who regularly teach this subject. The new teaching and assessment style was explained to them and the materials (with solutions) were provided each week. Two tutors were especially hostile to the introduction of collaborative learning, in particular, to their changed role in the classroom. One tutor resigned half way through the semester. The other made representation to the subject coordinator and Head of Department because he felt that the students were not learning anything (because he was not teaching them).

**Plan:** This is the focus of the next iteration of the action plan and involves:

- careful selection of tutors
- training and support for them to adapt to a new teaching style
- tutor involvement in design of materials and active observations of classes
- peer observations of other classes
Observe: Change the focus of the investigation to the tutors and observe their teaching.

9.10 Directions for future research

Some directions for future research have been highlighted by this project. First up, the issue of conceptual learning with CAS and in a collaborative learning environment needs to be addressed. For instance, we do not know yet just how the replacement of much rehearsal with pen-and-paper by CAS work will affect the learning of particular concepts or how collaborative learning will influence the design of assessment tasks. Povey and Ransom (2000, p57) found that students expressed concern about losing control (in relation to CAS):

The implication is that if you don't know 'how the computer did it', then you don't 'understand' and it is out of your control. This particular choice of words is interesting because, of course, computers and calculators do not do calculations the same way people do. Even when people realize that this phrase is not to be taken literally, they can find it hard to let it go because it serves as a metaphor for 'understanding'.

Research in the use of CAS and in the use of collaborative learning techniques must address issues of what understanding and concepts mean to staff and students.

Another area for future research is linked to the first and looks at developmental research that needs to be carried out into new ways of incorporating CAS and collaborative learning methods more deeply into teaching and learning activities. This research should be carried out as cooperative ventures with teaching staff. Active researchers in mathematics would be encouraged to participate as mentors and as providers of authentic tasks. The creative and innovative aspects of solving real problems with new tools and engaging with the changing technical context for making new mathematics would take precedence.


CHAPTER NINE: IMPLICATIONS OF FINDINGS & CONCLUDING REMARKS

9.11 Concluding remarks

Research, theory and practice all inform and influence each other. An important role for theory and research in education is to facilitate reflection on current practice and to point to possible future practices. Any activity that one wishes to take up – be it learning to use technology and knowing how to integrate it into teaching and learning, or learning how to facilitate group discussions, or how to work together in groups - is always directed by a purpose. As Coupland (2004) puts it: "no purpose, no activity: no purpose to change, no change" (p211).

There is a tension arising from the curriculum challenges of new technologies - tools such as graphing calculators and computer software that operationalise much of the traditional mathematics syllabi. So too, with introducing collaborative learning methodologies in terms of having to think about new and improved assessment tasks – tasks that promote and foster deeper thinking and conceptual understanding of concepts.

Yet the response from parts of the educational system in Australia is slow adoption. One reason for the slowness is the continuing notion that mathematics exists separately somewhere in people's heads and in books, and not in people's practices or activities. As long as this is the prevailing belief of mathematics educators and the wider community as well, tools for learning and doing mathematics will not be as highly valued as they clearly are by those making and using new mathematics.

The practice of mathematics has always been purposeful, tool-mediated and conducted in a social context. In the university sector, there are fewer obstacles to change in comparison to change at the school level, in terms of equity concerns and the inertia of large bureaucracies. Obstacles are still however found in the learned attitude that individual pen-and-paper mathematics is mathematics. The delay appears to be around the following issues:

1. Unfamiliarity of staff with new software tools;
2. Unfamiliarity of staff with new instructional methodologies such as collaborative learning;
3. Unfamiliarity of staff with taking up new roles such as facilitators;
4. Concern that pen-and-paper skills will be lost;
5. Concern that students with low computing skills will be disadvantaged; and
6. Concern that students with low group-work skills will be disadvantaged.

My research looked at first-year students' experiences of learning mathematics using computer technology and collaborative learning techniques. This research has provided insight into the dynamics behind some of the issues above, and it has also raised questions for future research.

This investigation has proved tremendously rewarding. The review of the literature has provided many pointers and suggestions into ways in which I can improve the use of collaborative learning methodologies as well as the use of computer algebra systems in my own teaching, in addition to increasing confidence in continuing to use such methods. The results of the project itself have suggested ways in which I might structure collaborative lessons, in order to further increase the learning opportunities for all students.

It is hoped that the results of this project may serve as a means of promoting more widespread use of collaborative learning and computer algebra systems within tertiary mathematics classrooms across Australia, and in tertiary institutions around the world. I leave you, the reader, with these quotes:

Tell me and I’ll forget; show me and I may remember; involve me and I’ll understand

- Native American proverb -

I never teach my pupils, I only attempt to provide the conditions in which they can learn

- Albert Einstein-
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¹ PATT = Pupil’s Attitudes Toward Technology


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Appendices
Appendix A1

letter

S.L. T."
3 March 2003

Ms Leigh Wood
Department of Mathematical Sciences
Faculty of Science
Level 15, Tower Building
Broadway Campus

Dear Leigh

UTS HREC 03/3 - WOOD, Ms Leigh, PETOCZ, Dr Peter (for D’SOUZA, Ms Sabita Maria - PhD student) - “Enhancing tertiary students’ mathematical understanding through computer supported collaborative based learning and assessment techniques”

Thank-you for your response to my letter of 17 February 2003. I have no hesitation in approving your application on the basis of the response.

You approval number is HREC 03/3A.

The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. The attached report form must be completed at least annually, and at the end of the project (if it takes more than a year), or in the event of any changes to the research as referred to above, in which case the Research Ethics Officer should be contacted beforehand.

I also refer you to the AVCC guidelines relating to the storage of data. The University requires that, wherever possible, original research data be stored in the academic unit in which they were generated. Should you submit any manuscript for publication, you will need to complete the attached Statement of Authorship, Location of Data, Conflict of Interest form, which should be retained in the School, Faculty or Centre, in a place determined by the Dean or Director.

Please complete the attached (green) report form at the appropriate time and return to Susanna Davis, Research Ethics Officer, Research Office, Broadway. In the meantime, if you have any queries please do not hesitate to contact either Susanna or myself.

Yours sincerely,

Jane Stein-Parbury
Associate Professor
Chair
UTS Human Research Ethics Committee
Appendix A2a

Information letter and consent forms

Dear Student,

My name is Sabita M. D'Souza and I am a PhD student at the University of Technology, Sydney, in the Department of Mathematical Sciences. I am conducting a research study entitled "Enhancing tertiary students' mathematical understanding through computer supported collaborative based learning and assessment."

The aim of this research is to investigate the effectiveness of collaborative group work in mathematics learning using technology such as the Computer Algebra System (CAS), Mathematica. This research study aims to facilitate deeper learning and understanding of concepts covered in the Mathematical Modelling 1 (33130) subject in a collaborative and technology-rich environment, and hopes to determine how useful and enjoyable you find this approach to learning. I would be very grateful if you are happy to cooperate with me in conducting this research study.

The design of the proposed study will include three methods of data collections - questionnaires, participant observation, and interviews. An initial 'pre-study' questionnaire will be administered at the start of the Autumn Semester 2003 to determine your preferred learning style and should require about 15-20 minutes of your time. The second method of data collection will involve observations of students working collaboratively on activities in tutorials as well as during laboratory classes. I would also like volunteers to spend about 40-60 minutes to talk with me about their opinions on collaborative learning, working with Mathematica and assessment issues. Your responses will be audio taped. Towards the end of semester, you will be asked to complete a 'post-study' questionnaire on your learning styles after having participated in the study to detect any change in your learning styles preferences. This should take no more than 15-20 minutes of your time. All data collected for this study will be coded for ethical considerations and will be anonymous. You are free to withdraw from this study at any time without giving a reason. You will not be affected in any way for non-participation in this study. In addition, this study will not affect your coursework or assessment in any way. However, it is hoped that participation in this study might help improve your understanding of and performance in this subject. You will be shown the results of the questionnaires which may aid in reflecting on your style and process of learning. Any research data gathered from this project will be published in a form that does not identify you in any way.

As with all research projects, it is important and necessary to inform all participants of the proceedings and channels through which they may communicate any concerns they might have. For general contact on the day-to-day running of the research project, you can contact me on (02) 9514 2275 or email sabita.dsouza@uts.edu.au. You can also contact either of my supervisors: Ms. Leigh N. Wood on (02) 9514 2268 or email leigh.wood@uts.edu.au, or Dr. Peter Petocz on (02) 9514 2264 or email peter.petocz@uts.edu.au. You can also write to any of us at: Department of Mathematical Sciences, Faculty of Science, University of Technology, Sydney, PO Box 123, Broadway, NSW 2007.

This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer, Ms Susanna Davis on (02) 9514 1279 or email susanna.davis@uts.edu.au. You can also write to her at: The Research Office, Level 7, Tower Building, City Campus, University Technology, Sydney, PO Box 123, Broadway, NSW 2007. Any complaint you make will be treated in confidence and investigated fully and you will be notified of the outcome.

Thank you and look forward to working with you!

Yours Sincerely,

Sabita D'Souza
Appendix A2b

Sample participant consent form (To complete questionnaires)

I hereby consent to participate in the research study entitled "Enhancing tertiary students’ mathematical understanding through computer supported collaborative based learning and assessment techniques" being conducted by Ms. Sabita M D'Souza, Department of Mathematical Sciences, Faculty of Science, University of Technology, Sydney, PO Box 123, Broadway, NSW 2007, Telephone (02) 9514 2275, email sabita.dsouza@uts.edu.au.

I understand that the purpose of this study is to investigate the effectiveness of collaborative group work in mathematics learning using technology such as the Computer Algebra System (CAS), Mathematica and to determine how useful and enjoyable I find this approach to learning.

I understand that my participation in this research study will involve four questionnaires and possible observations of collaborative group work during tutorial and laboratory sessions.

I am aware that I can contact Ms. Sabita M D'Souza or her supervisors Ms. Leigh N. Wood or Dr. Peter Petocz if I have any concerns about the research. I also understand that I am free to withdraw from the study at any time without having to give a reason. I understand that I will not be affected in any way for non-participation in this study and that this study will not hinder my coursework or assessment in any way. I also understand that my participation in this study might help improve my understanding of and performance in the Mathematical Modelling 1 subject. I agree with the fact that any research data gathered from this study may be published in a form that does not identify my in any way.

I understand that this study has been approved by the University of Technology, Sydney Human Research Ethics Committee and if I have any ethical matters or complaints about any aspect of my participation in this study, I may contact the Ethics Committee through the Research Ethics Officer, Ms. Susanna Davis on (02) 9514 1279 or email her at susanna.davis@uts.edu.au. I also understand that any complaint I make will be treated in confidence and investigated fully and that I will be notified of the outcome.

<table>
<thead>
<tr>
<th>Name of participant:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Number:</td>
<td></td>
</tr>
<tr>
<td>Signature of participant:</td>
<td></td>
</tr>
<tr>
<td>Date signed:</td>
<td>------- / ------- / -------</td>
</tr>
</tbody>
</table>
Appendix A2e

Sample participant consent form (To be interviewed)

I hereby consent to being interviewed as part of the research study entitled "Enhancing tertiary students' mathematical understanding through computer supported collaborative based learning and assessment techniques" being conducted by Ms. Sabita M D'Souza, Department of Mathematical Sciences, Faculty of Science, University of Technology, Sydney, PO Box 123, Broadway, NSW 2007, Telephone (02) 95142275, email sabita.d souza@uts.edu.au.

I understand that the purpose of this interview is to talk about my opinions and/or feelings about collaborative learning, working with the Computer Algebra System, Mathematica and assessment issues involved.

I understand that my participation in this interview is voluntary and will take approximately 40-60 minutes.

I am aware that I can contact Ms. Sabita M D'Souza or her supervisors Ms. Leigh N. Wood or Dr. Peter Petocz if I have any concerns about the research. I understand that I will not be affected in any way for non-participation in this interview and that it will not hinder my coursework or assessment in any way.

I agree with the fact that any research data gathered from this study may be published in a form that does not identify me in any way.

I understand that this study has been approved by the University of Technology, Sydney Human Research and if I have any ethical matters or complaints about any aspect of my participation in this study, I may contact the Ethics Committee through the Research Ethics Officer, Ms. Susanna Davis on (02) 9514 1279 or email her at susanna.davis@uts.edu.au. I also understand that any complaint I make will be treated in confidence and investigated fully and that I will be notified of the outcome.

<table>
<thead>
<tr>
<th>Name of participant:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Number:</td>
<td></td>
</tr>
<tr>
<td>Signature of participant:</td>
<td></td>
</tr>
<tr>
<td>Date signed:</td>
<td>------ / ------ / ------</td>
</tr>
</tbody>
</table>
Appendix A3

Post study questionnaire demographic information

Participation in completing this survey is voluntary, but it is hoped that responses from many students will be received, particularly those who were involved in group work during the semester. I thank you for giving up your time to answer this questionnaire which is intended to increase understandings of the ways in which group work affects student learning. To be of fullest use, it is important that you answer every sub-section of each question by providing the response, which most closely matches your experience or opinion. Each question is designed so that there are no right or wrong answers. It is your responses to the questions that are important.

Section A: Personal Information

Name

_____________________________________________

Student ID

_____________________________________________

Age

_____________________________________________

Gender

[ ] Male

[ ] Female

Number of Years in Australia

_____________________________________________

Language Spoken at Home

_____________________________________________
Appendix A4

Questionnaire on learning styles

Instructions
Students learn in many different ways. For instance, some students learn primarily with their eyes (visual learners) or with the ears (auditory learners); some students prefer to learn by experience and/or by 'hands-on' tasks (kinesthetic or tactile learners); still some students learn better when they work alone while others prefer to learn in groups. This questionnaire has been designed to help you identify the way(s) you prefer to learn. Read each statement on the following pages. Please respond to the statements as they apply to your study of mathematics. Decide the degree to which you agree or disagree with each statement and then tick the appropriate box.

<table>
<thead>
<tr>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td>disagree</td>
<td>Neutral</td>
<td>agree</td>
<td>Strongly agree</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Please respond to each statement quickly, without too much thought. Try not to change your responses after you choose them. Please answer all the questions. Please use a pen to mark your choices.
<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>When the teacher gives me the instructions, I understand better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>I prefer to learn by doing something in class.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>I get more work done when I work with others.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>I learn more when I study with a group.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>In class, I learn best when I work with others.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>I learn better by reading what the teacher writes on the board.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>When someone tells me how to do something in class, I learn it better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>I learn better when I do things in class.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>I remember things I have heard in class better than things I have read.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>When I read instructions, remember them better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>I learn more when I can make a model of something.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>I understand better when I read instructions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>When I study alone, I remember things better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>I learn more when I make something for a class project.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>I enjoy learning in class by doing experiments.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>I learn better when I make drawings as I study.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>I learn better in class when the teacher gives a lecture.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>When I work alone, I learn better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>I understand things better in class when I participate in role-playing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>I learn better in class when I listen to someone.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>I enjoy working on an assignment with two or three classmates.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>When I build something, I remember what I have learned better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>I prefer to study with others.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>I learn better by reading than by listening to someone.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>I enjoy making something for a class project.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>I learn best in class when I can participate in related activities.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>In class, I work better when I work alone.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>I prefer working on projects by myself.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>I learn more by reading textbooks than by listening to lectures.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>I prefer to work by myself.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix AS

Questionnaire on attitudes towards group work and objectives for setting group work

Part I:
Lecturers and course coordinators have certain objectives in mind in setting group work. Some of these objectives are listed below. In your opinion, how relevant are they to your educational needs?

<table>
<thead>
<tr>
<th>Objective</th>
<th>Not at all relevant</th>
<th>Somewhat relevant</th>
<th>Extremely relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>To encourage an attitude of cooperation as opposed to competition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To encourage notions of trust and reliance on other students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To develop skills in organising and coordinating tasks and outcomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To provide opportunities to teach and learn from other students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To stimulate student responsibility for their own learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To encourage students to respect and value other students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To develop conflict resolution skills</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To enhance in students the motivation to learn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To stimulate thought about the course content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To increase understanding of the course content</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part II:

Please answer the following questions

Can you state up to three benefits you gained from doing group work in this subject?

1. 
2. 
3. 

Can you state up to three drawbacks for you of doing group work in this subject.

1. 
2. 
3. 

Please suggest any improvements which you think could be made to group work in this subject.

Have you been involved in group based tasks in any other subject this semester. If yes, please give details.

1. 
2. 
3. 
4. 
Appendix A6

Questionnaire on attitudes towards using computers

The purpose of this part of the questionnaire is to assess students' attitudes toward using computers. The results from this part will be used to predict how students' attitudes toward using computers influence learning and motivation. It is also expected that information gained may help instructors make the use of computers a more productive and enjoyable experience. Please answer the following items as honestly as possible. Answer the items as they apply to your study of mathematics. For each of the statements, tick the option that most closely corresponds to how you think and feel about the statement.

<table>
<thead>
<tr>
<th>SA</th>
<th>A</th>
<th>MA</th>
<th>N</th>
<th>MD</th>
<th>0</th>
<th>SO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Mildly Agree</td>
<td>Neutral</td>
<td>Mildly Disagree</td>
<td>Disagree</td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>Item</td>
<td>Description</td>
<td>SA</td>
<td>A</td>
<td>MA</td>
<td>N</td>
<td>MD</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1</td>
<td>If I can avoid using a computer, I will.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>The way computers force you to follow a procedure annoys me.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>I will work at a computer for long periods of time to successfully complete a task.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>I enjoy thinking up new ideas and examples to try out on a computer.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Using a computer makes learning more enjoyable.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>I like the freedom to experiment that is provided by a computer.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>I have a lot of self-confidence in using computers.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>I feel more confident of my answers with a computer to help me.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>If the computer program I am using goes wrong, I panic.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>I feel nervous when I have to learn new procedures on a computer.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>I am confident that I can master any computer procedure that is needed for my course.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>I do not trust myself to get the right answers using a computer.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>If I make a mistake when using a computer, I am able to work out what to do for myself.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Computers help me learn better by providing many examples to work through.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>I find it difficult to transfer understanding from a computer screen to my head.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>Using computers helps me understand concepts better.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>By taking care of messy calculations, computers make it easier to learn essential ideas.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>When I read a computer screen, I tend to gloss over the details of the mathematics.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>Following keyboard instructions takes my attention away from the mathematics.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>Computers help me link knowledge e.g. the shapes of graphs and their equations.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Appendix A7

Questionnaire on attitudes towards group based assessment

This questionnaire has been designed to help you express your attitudes towards group assessment. Read each statement on the following pages. Please respond to the statements as they apply to your study of mathematics. Decide the degree to which you agree or disagree with each statement and then tick the appropriate box.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I would rather choose my fellow group members than be allocated to a group by a tutor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Automatically granting each group member the same grade for a group task is unfair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>I think it is important that I should take part in a group task as part of my studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Group assessment should be used ONLY to measure an individual’s ability to work in a group</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td>Group assessment tends to ‘bunch’ the marks for a given cohort of students</td>
<td></td>
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<td>6</td>
<td>Peer assessment methods are a fair way of distributing marks in a group task</td>
<td></td>
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<tr>
<td>7</td>
<td>I would rather undertake an individual task than a group task</td>
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<tr>
<td>8</td>
<td>I have not yet met a method of group assessment which is fair to all group members</td>
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<tr>
<td>9</td>
<td>With individual assessment in groups, group members can become competitive with each other and not share their resources and ideas</td>
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<tr>
<td>10</td>
<td>Groups assessments allow students to ‘hide’ more easily than with individual tasks</td>
<td></td>
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<tr>
<td>11</td>
<td>Group assessments tend to penalise able students</td>
<td></td>
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<td></td>
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<tr>
<td>12</td>
<td>Group assessment methods are not as reliable as individual assessment</td>
<td></td>
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<tr>
<td>13</td>
<td>Before undertaking a group assessment students should learn how to work in a team</td>
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<tr>
<td>14</td>
<td>There are often more disagreements and conflicts over the allocation of tasks</td>
<td></td>
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<tr>
<td>15</td>
<td>Groups assessment tend to benefit less able students</td>
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</tbody>
</table>
Appendix A8

Excel spreadsheet containing coded questionnaire data

- See excel spreadsheet named "Questionnaire_data_set_coded" on CD-ROM

- See word document named "Part IIQI-4Responses" on CD-ROM for Part II of Appendix AS

Interview transcripts

- See word document named "Outcome Space" on CD-ROM
Appendix A9

Sample tutorial

Topic: Functions and Graphs

Question 1 (Language)

a. In December 2000, the temperature in Sydney was unusually low over the summer vacation. The daily high temperatures for 21-27 December 2000 are given in the table below. Decide on suitable independent and dependent variables for this problem.

<table>
<thead>
<tr>
<th>Date</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp (OC)</td>
<td>20</td>
<td>17</td>
<td>19</td>
<td>10</td>
<td>20</td>
<td>11</td>
<td>16</td>
</tr>
</tbody>
</table>

b. Pressure $p$ is exerted on the hull of a submarine at a depth $h$. Explain how we can regard either of the variables $p$ or $h$ as the independent variable and the other as the dependent variable. Suggest a reasonable domain when $h$ is the independent variable.

c. Hypothetical data for the Tower of Terror are given in the table below, where $h$ is the height (metres) at time $t$ (seconds). Suggest reasons why we have to take $t$ as the independent variable rather than $h$. What is a reasonable domain for $t$?

<table>
<thead>
<tr>
<th>$t$</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h$</td>
<td>15.0</td>
<td>54.1</td>
<td>83.4</td>
<td>102.9</td>
<td>112.6</td>
<td>112.5</td>
<td>102.6</td>
<td>82.9</td>
<td>53.4</td>
<td>14.1</td>
</tr>
</tbody>
</table>

d. Hypothetical census data for the population of a country region is given in the table below. Decide on suitable independent and dependent variables for this problem. Is there only one possible choice? Plot a graph of the data and use the data to predict the population in 2000. Can you be confident that your prediction is correct? Explain.

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (millions)</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>18</td>
</tr>
</tbody>
</table>

Question 2 (Concept)

1. A brief description of a physical situation is given below. For the indicated variable, state a reasonable domain.
   a. A parking deck is to be built; $x =$ width of deck (in meters)
   b. A new candy bar is to be sold; $x =$ number of candy bars sold in the first month

2. Discuss whether you think $y$ would be a function of $x$:
   a. $y =$ grade you get on an exam; $x =$ number of hours you study
   b. $y =$ probability of getting lung cancer; $x =$ number of cigarettes smoked per day