Reconsidering the Nature

of

Mathematics Teaching

and

School Mathematics

Curriculum

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Abstract

This thesis contains two distinct elements. The first relates to the original intention to develop a technological tool that helps mathematics teachers become micro-researchers within their own classrooms. This tool, the Real Time Feedback System, consists of a wireless network that connects a set of iPod Touch devices to a database and web server in the classroom that intermittently prompts students to respond to a set of questions written by their teacher. The responses to these questions are automatically collated into a graphical format, allowing teachers to gather live data and reflect on the progress of their lessons without the burden of manual collection and collation of student responses. The intention was that the tool would facilitate teacher reflection, resulting in improved teaching of mathematics.

While the system was successful in stimulating teacher reflection, and generated enthusiastic suggestions of how it could be improved to better suit their purposes, the teachers involved in trialling the tool did not incorporate it, unaided, into their everyday practice. I took this to signify that my original aim of equipping teachers in this way was perhaps premised on an unrealistic expectation of what could be asked of teachers. This observation prompted a gestalt shift in my perspective and I began to notice unrealistic expectations embedded in the teacher reflection literature and other mathematics education research literature. I became aware of an absence of any clear sense of what constitutes reasonable expectations of mathematics teachers, and this analysis led me away from the original research aims and gave rise to the second intention of this thesis, that of seeking to reconsider the nature of mathematics teaching and school mathematics education, and the expectations that many commentators have of teachers.

This reconsideration involves an exploration of aspects of teacher participation in research and professional development, how they judge their teaching practice, what implications there might be for students, and in turn what implications there might be for school mathematics. It begins with a discussion of idealism within mathematics education research centred on a detailed consideration of some researchers' expectations of teachers and additional analysis of data relating to teachers' willingness to be observed by researchers. Methodological issues that arise pertaining to the nature of observation are examined and it is suggested that this may be indicative of a gap existing between researcher idealism and teacher pragmatism.

This analysis continues with the presentation of further survey data which indicate that teachers work long hours, are committed to their jobs, and yet despite this many seem to lack knowledge or confidence in teaching mathematics. A second group of teachers are identified who, while reporting high levels of mathematics knowledge and confidence, appear to have attitudes toward their students that could impact negatively on their ability to teach mathematics. The existence of these two groups prompts an exploration of inequity within mathematics and the proposal of a process of *random inequity* that could disadvantage many students.

The consideration of these various forms of inequity within mathematics education prompts an analysis of the nature of school mathematics and the identification of special interest groups that seek to shape mathematics curriculum to their own ends. It is argued that pressure from these groups termed, using the categories from Ernest (1991): Industrial Trainers; Technological Pragmatists; Old Humanists; Progressive Educators; and, Public Educators, has a negative impact on the ability of teachers to teach mathematics successfully by forcing them to meet demands imposed by others that take little account of the demands inherent to being in the classroom.

It is finally argued that, as a result of the success of certain groups bending mathematics curriculum to serve their own purposes, school mathematics has become disconnected from peoples' lives. It is suggested that a different approach to the mathematics curriculum based on the realistic needs of educated adults and realistic expectations of what competent teachers can teach, could result in a mathematics better suited to the needs of society. It is argued that a curriculum based on functional numeracy, financial numeracy, citizenship numeracy, critical mathematics, and aesthetic mathematics could result in mathematics that is more teachable and more relevant to students.

Statement of authorship

This thesis contains no material which has been submitted for examination in any other course or accepted for the award of any other degree or diploma in any university and, to the best of my knowledge and belief, contains no material previously published by another person except when due reference is made in the text.

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Richard O'Donovan

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CHAPTER 1

The Context of the Thesis

> "…no one can be really esteemed accomplished, who does not greatly surpass what is usually met with. A woman must have a thorough knowledge of music, singing, drawing, dancing, and the modern languages, to deserve the word; and besides all this, she must possess a certain something in her air and manner of walking, the tone of her voice, her address and expressions, or the word will be but half deserved."
>
> "All this she must possess," added Darcy, "and to all this she must yet add something more substantial, in the improvement of her mind by extensive reading."
>
> "I am no longer surprised at your knowing *only* six accomplished women. I rather wonder now at your knowing *any*." (*Jane Austen*, Pride and Prejudice)

1.1 ***Introduction***

This research began as an attempt to develop, test, and evaluate a new technological approach to facilitating mathematics teacher professional development through reflective practice. The intention was to equip teachers with a tool that could easily capture data from their students which they could use to inform their teaching practice. However, the intended destination proved to be the starting point of what ultimately has become a journey into exploring the gaps that appear to exist between the expectations and practical realities associated with school mathematics. I have found myself, somewhat like Elizabeth in *Pride and Prejudice*, marvelling at the bevy of accomplishments that are often expected of mathematics teachers. So what began as a conventional doctorate has morphed into a series of smaller, self contained analyses that led through an argument which reconsiders the nature of mathematics teaching, the nature of school learning, the nature of mathematics curriculum, and what these mean for school mathematics.

Before committing myself to this research I looked closely at a number of theses as well as reading books about the structure and processes of writing theses. However, as my research progressed I found myself being led in unanticipated directions, and therefore decided to deviate from the usual thesis template. As a result, rather than reporting exclusively and exhaustively on the original research project, this work traces the progression of my thinking as I set out to develop ways to improve school mathematics teaching, and ended up critiquing school mathematics itself. Thus, rather than an extensive account of the originally intended destination, this work is more akin to a description of an unexpected journey undertaken soon after arrival. Consequently the content and order of this thesis are somewhat different from the norm. A conventional thesis consists of a context, literature review, methodology, results, and implications, however this thesis is not like that. The intention here is to present an argument that has arisen from the course of my research, so rather than being split out into discrete sections, relevant literature, data, and analysis are often presented in a more amalgamated manner, reaching conclusions that sometimes challenge the received view.

To help clarify the overall direction of this thesis, this chapter consists of four main parts. The first, Section 1.2 Overview of the journey, gives an outline of the contents of each chapter of the thesis. The second section presents details of the broader project within which this research was undertaken, while the third gives some details of my own background. Last is a small section on the original research questions that drove the initial lines of enquiry.

1.2 Overview of the journey

The following sub-sections correspond to each of the chapters presented in this thesis such that the final number with the sub-section numbers corresponding directly to the relevant chapter. That is, the third number in the heading numbering system denotes the chapter it describes (e.g., 1.2.1 relates to Chapter 1, 1.2.2 relates to Chapter 2, 1.2.3 relates to Chapter 3, and so on).

1.2.1 The context of the thesis

The first chapter provides a summary of the key stages of my research and an outline of the overarching argument. As described above, the first section is structured in a similar manner to the entire thesis and provides a quasi abstract for each of the chapters that follow. The three other sections provide some details on the background and context in which the work was undertaken.

1.2.2 The initial goal: The Real Time Feedback System

The original destination, outlined further in Chapter 2 and O'Donovan (2008), was to explore a way to foster teacher learning while working within the constraints imposed by what Connelly and Clandenin (1995) described as the secretive nature of teaching. Central to this task was to explore the role that teacher reflection could play in forming the basis for professional communities (Feinman-Nemser, 2001). The intention was to develop a technological tool that would enable mathematics teachers to easily capture 'live' data from their students during class and provide graphical tools to assist teachers in analysing student responses to research questions the teachers posed. The rationale was that such an approach would enhance teachers' capacity to reflect on their practice and thereby lead to improvements since they could easily collect and analyse empirical data on topics of interest to them in real time, and fully under their own control.

To these ends an electronic feedback system was developed, the Real Time Feedback System (RTFS). This consisted of a laptop computer acting as a database and web server. The laptop hosted an interface for teachers to enter details about their class (student name, gender, age group, ability group etc.), and to configure a set of pedagogical questions that they would like to collect responses to throughout any given lesson (e.g., How hard are you trying at the moment?). Students were each given a handheld computing device, an *iPod Touch*, which could be used to browse the web pages generated by the laptop over an ad hoc local area network via WiFi connectivity. Students were prompted to respond to the set of questions after a nominated period of time, say every 10 minutes. Depending on the teacher, students also used other features of the iPod Touch (e.g., the calculator) to help complete their work during the intervals between responses. The laptop also recorded the audio of the lesson in order to be able to identify retrospectively what was happening in the class during any particular response period.

At the end of the lesson, or any other convenient time, the teacher reviewed the feedback on the laptop in one of several graphical formats. Depending on the information originally configured, teachers could view data from individual students, the entire class, or subsets thereof (e.g., responses by ability group, sex, age etc.). The digital audio recording was also available should the teacher wish to jog their memory as to what was happening at any given time of interest.

In addition to outlining the nature of the RTFS, Chapter 2 also reviews some of the relevant literature and methodological issues related to the initial approach.

1.2.3 Developing and using the RTFS

Chapter 3 outlines some of the details pertaining to the development of the RTFS and then turns to a number of case studies that were undertaken with teachers using the RTFS. In each of these the teachers selected or provided questions of interest to themselves while I set up the equipment and familiarised students with how to use the iPod Touch devices. At the end of the lessons the teachers took part in a semi-structured interview whilst reviewing the collected data. The main research question behind the interviews was to investigate the extent to which teachers engaged in professional reflection, and how useful the RTFS was in stimulating such reflection. Further details of case studies are provided in Chapter 3 and O'Donovan (2009), although due to the subsequent change in focus of the project these case studies are not dealt with in extensive detail.

The analysis of these interviews suggests that teachers quickly moved beyond Van Manen's (1977) notion of technical reflection towards more desirable critical reflection of their practice, although it is possible to view their reflections in a less generous light. In fact, the different readings of the level of teacher reflectivity played an important role in derailing the original intention of this research project as is explained below. The teachers themselves reported that they saw considerable potential for the use of the RTFS in helping improve their pedagogical practice, and even made suggestions and requests for how it could be further enhanced.

Various modifications were made to the RTFS to incorporate these suggestions and opportunities were then given to teachers to use the equipment unaided. The kit was left with three teachers for several weeks with the offer of immediate support via email or mobile phone should they require it. After each of these loan periods none of the teachers had managed to 'get around' to using the system. This started to raise doubts in my mind as to how realistic it was to expect teachers to adopt new technology in what is already a very busy workplace.

Such doubts, coupled with the different possible interpretations of the depth of the teachers' reflections gave me pause. Turning a critical gaze upon critical reflection, that is, reflecting critically on the interpretation of the data I had captured, led me to conclude that on the one hand the teachers appeared to be highly professional and student centred yet, arguably, no more than *technically,* or superficially, reflective from other perspectives (e.g., Day, 1993; Tremmel, 1993; Valli, 1997; and Zeichner & Liston, 1996). The possibility that these teachers could be viewed as sub-standard from the perspective of the reflection literature began to make me wonder if too much was being expected of mathematics teachers.

1.2.4 Expectations and observations in research

These concerns about such high expectations being placed on teachers prompted me to re-read the reflective practice literature from the perspective of a practising teacher. Chapter 4 explores the broader concerns about the idealism and unreality that appeared to be inherent in what was being advocated within this literature. Many definitions of critical reflection emphasised its role as a process of self-development, political action, and social reform, all of which fall well beyond the scope of a typical classroom, and certainly beyond what is usually associated with a workplace.

Casting this critical gaze further afield started to uncover instances of unrealistic idealism across other areas within mathematics education research. One area of note within the broader project within which this research took place was the issue of whether teachers 'nailed' lessons or not. That is, did they make the most of learning opportunities with students to realise the most important mathematical concepts being covered. In other areas researchers also sometimes seem to focus on their own narrow areas of interest and expect teachers to be giving a similar degree of attention to relevant details as they did themselves, somewhat like the distinction made by Schön (1983) between the *knowledge-in-action* of teachers in the "swamp" versus the "high ground" perspective of researchers. It struck me that there did not seem to be a clear picture of what constituted a good teacher since they could always be seen to be failing on some measure or other because of the perfectionism that appeared to exist within the education research literature.

For instance, the idealism in some of the reflection literature seemed to place super-human responsibility on teachers, somewhat reminiscent of the high expectations many women place on themselves to be perfect mothers. This evoked Winnicott's (1958) notion of the *good-enough mother* wherein the notion of a perfect mother is both unrealistic, unsustainable, and ultimately unhelpful to the development of the child while a good-enough mother does what she can for the child, but has natural limitations that help to foster further developments in the child. The analogous thought arose that perhaps instead of striving for perfection in pedagogy it was better to conceive of a *good-enough teacher* and, instead of advocating perfectionist ideals, establishing an ideal to which teachers could realistically aspire, and actually attain. In this sense a *good-enough teacher* would not be someone who is merely an adequate teacher, but rather someone who is as skilled as can reasonably be expected of teachers and who can form good relationships with students that optimise their opportunities for learning.

This raised for me the question of whether teachers themselves had a clear sense of what constituted a good teacher, how they perceived themselves in this regard, and how this related to some of their work practices. This prompted the development of a survey, which yielded results showing that teachers derived their sense of how well they were doing from their students rather than from professional development. This underscored the gap between mathematics education research and chalk face pedagogy, and perhaps indicated the increased need for tools like the RTFS so that teachers could conduct their own research into their own practice. However, paradoxically the RTFS arose from a research context, and while teachers claimed to value it, it did not actually fit into their normal routine, and they did not value it so much as to change their routine to accommodate it. In this way it was like much other professional development which seemed good on the day, but became unachievable in the practical reality of the classroom.

1.2.5 Teachers' sense of success

The failure of professional development to be incorporated into pedagogical practice could arise from teacher complacency. Chapter 5 reports survey data that shows teachers generally had a high regard for their own teaching skills, which may well have accounted for the reason that RTFS was treated as a 'nice but not necessary' addition to their practice. However, when it came to teaching mathematics, over 30% of the teachers felt that there were gaps in their abilities. The data collected showed a strong correlation between teachers' reported level of confidence in teaching mathematics with what Shulman (1986) described as *subject content knowledge* (SCK). Those with higher levels of confidence in teaching mathematics typically reported feeling comfortable with their level of SCK while those unconfident in teaching mathematics were concerned with possessing lower levels of SCK. Further investigation of this phenomenon evoked responses from unconfident mathematics teachers that were consistent with them suffering from a degree of *mathematics anxiety* (Kogelman & Warren, 1978).

I assumed that such anxiety could be reasonably expected to have a negative impact on these teachers' ability to teach mathematics effectively, and that it was unlikely to be helped by a reflective tool, so I wished to gather further insight into this phenomenon. I speculated that mathematically anxious teachers might avoid allowing their students to struggle with mathematics problems due to equating struggle with anxiety. Similarly, I thought it might be that these unconfident teachers would project features associated with mathematics anxiety onto their students who were experiencing difficulties, thus attributing to them poor memories, a lack of interest in learning, or as giving up easily.

It was possible to test these hypotheses by matching responses to two different surveys. What emerged from the analysis was that not only were these hypotheses rejected, but that almost the reverse was the case, that is, the unconfident teachers viewed their students in a similar way to confident teachers, but instead a distinct subset of confident mathematics teachers appeared to hold overly pessimistic views of their students' abilities. So while the unconfident mathematics teachers (33% of the respondents) did not attribute mathematically anxious qualities to their students to any discernibly different extent than the general population of teachers surveyed, a group of confident mathematics teachers (approximately 17% of the sample) did appear to perceive their students as possessing characteristics that it was assumed could impede these teachers' being able to teach properly.

Such a result raised the possibility that up to 50% of mathematics teachers either felt that they lacked the skills to do the job properly or, having adequate skills, felt unable to do the job properly because of their students' attributes. The implications of this for students are particularly concerning given the largely sequential nature of mathematics curriculum in schools and the prospect that only every second teacher might be relied upon to confidently teach mathematics to *all* students.

If such a scenario is an accurate reflection of reality, then the prospects of all students having an equal opportunity to learn mathematics would be impeded. If such a high percentage of teachers were less than fully confident in their abilities to teach all students, then by chance alone, a significant percentage of students might be expected to have a run of three years without having a fully confident/considerate mathematics teacher. From an equity perspective this would place such students at a significant disadvantage, and could reasonably be expected to reduce their prospects of mathematical success through no fault of their own.

1.2.6 Educational inequity and school mathematics

Chapter 6 is premised on the importance of equity being particularly relevant to mathematics education. It is uncontroversial to note that mathematics occupies a prestigious position in the school curriculum and appears to be highly valued by society. This exacerbates the problem of what might be considered as *random inequity*. Unlike systematic inequity or bigotry, there is no overt discrimination per se, but rather the potential for a considerable proportion of the population of students to nevertheless be disadvantaged due to structural flaws, in this case, being taught for several consecutive years by teachers who jeopardise their mathematics achievement.

This struck me as intractable. Teachers generally appeared to be doing their best, working long hours, engaging in professional development, yet many still lacked mathematical confidence. And of those who felt confident in their mathematics knowledge, nearly one fifth held unsympathetic views towards students. Meanwhile pre-service teachers continued to exhibit signs of mathematics anxiety and/or less than ideal mathematical skills (Hawera, 2004; Uusimaki & Kidman, 2004; Wilson, 2007) which suggested that the problem was not going to be alleviated by a steady influx of new teachers. Also students who may not have experienced random inequity themselves may have parents who did, possibly predisposing them toward a negative attitude toward mathematics, or reducing their opportunities to be supported at home. At the very least it seemed that random inequity in mathematics education would be a feature of education into the foreseeable future.

There also seemed to be evidence that mathematics was a factor in student disengagement from school generally. Lee and Burkam (2003) found that 18% of school drop outs had avoided mathematics in their first two years of American high school compared to only 5% of non-drop outs. They suggest that student-teacher relations could hold the key to reducing drop out rates, observing that if the reported quality of these relationships had been higher such that the average increased by one standard deviation, this would correlate with an 86% lower rate of students dropping out. Other studies similarly indicated that improved student-teacher relationships reduced the likelihood of students dropping out, yet some mathematics teachers did not see these relationships as part of their role (e.g., "I'm a calculus teacher: I don't do student relationships" (Perso, 2006, p.40)). I was able to collect evidence confirming the positive impact of student-teacher relationships from a reengagement program that provided no remedial mathematics but provided opportunities to form strong student-teacher relationships. Students in this program experienced significantly positive flow on effect into their mathematics classroom compared to students of similar ability who did not participate in the program. Many studies have shown that adults and students demonstrate competence in mathematics they deem relevant that surpasses their performance in school-like circumstances (e.g., Abreu, 1995; Bishop & Abreu, 1991; Carraher, Carraher, & Schliemann, 1985; Schoenfeld, 1991).

These factors combined to raise the question for me of just how important mathematics was for students and how much of an impact random inequity might have on them. Students often hold the belief that mathematics is important to them in the future, even though the way it would be important is unclear to them (Toomey & O'Donovan, 1995). Popular accounts of the importance of mathematics sometimes appear to be more romantic than realistic, with many students routinely being advised by teachers that the more mathematics they do, the better.

Yet students rarely encounter adults engaging in formal mathematics outside of the classroom, and the career advice suggesting that mathematics is required for future employment often quote medical practitioner, lawyer, and research scientist as typical careers that use mathematics principles extensively. However others have suggested that over 90% of jobs in the Unites States of America (USA) did not require anything beyond primary school mathematics, and that the main reason mathematics played such a pivotal role in school curriculum was because of the ease with which it could be assessed (Redovich, 2006). A preliminary analysis of Australian employment data suggests that this 90% figure is a reasonable estimate for Australia as well. Given that only a small number of careers require higher level mathematics, unless there were other compelling reasons for doing so, it would seem that there may be an unreasonable emphasis on teaching mathematics in schools.

Other non-vocational reasons that have been put forward in support of ubiquitous mathematics education include: acquiring discipline in making arguments; stretching students' minds; familiarisation with intellectual rigour; understanding the beauty underlying nature; and, reasons around it being otherwise pedagogically beneficial to teach mathematics. Each of these is explored in the relevant chapter below, but in each case it seems that there may be a better approach to achieving such ends besides the use of mathematics.

It also became apparent that problems exist at the tertiary mathematics level. Conversations with university mathematics lecturers revealed that there are a number of instances where particular techniques are only used in the teaching of undergraduate courses. On these occasions even the academic mathematicians need to learn or re-learn the relevant techniques since they are not otherwise used. There is also evidence from the USA which indicates that mathematics PhD students are unable to secure employment within the tertiary sector, and that the demands for professional mathematicians has been in significant decline for the last two decades (Lowell & Salzman, 2007). Others have pointed out that many analytical tasks can now be performed with software which, once written, is readily adaptable to new applications. Also many mathematics PhDs are not well suited to solving real world problems (Mannix & Ross, 1995).

So while some aspects of mathematics have broad utility and relevance, such as statistics, there are many other areas which lack any obvious benefit for students. This view has direct implications for what should constitute school mathematics curriculum.

1.2.7 School mathematics and its place in society

It seemed to me that if the current mathematics curriculum is not as vital to student learning as it is often assumed to be, then a great deal of suffering might easily be avoided by modifying what mathematics is taught. Mathematics anxiety in both students and teachers alike could be reduced, and student disengagement from school and drop out rates might be improved.

There may also be a duty of care element to the teaching of mathematics in that mathematics anxiety could be viewed from the perspective of psychological injury.

Many adults have strong reactions to mathematics, and have developed social phobias as a result of the traumas they have experienced in the mathematics classroom. I suspect the deleterious impact mathematics has on many children, adolescents, and adults may have been underestimated and that there are occupational health and safety issues as well as duty of care issues relating to mental health which have been overlooked with regard to mathematics.

It is a telling point that quasi-therapeutic approaches are being adopted in some pre-service teacher courses, such as Wilson's (2009) bibliotherapy, which assist adults overcome the psychological injuries they had sustained with regards to mathematics. Given that pre-service primary school teachers exhibit some of the highest levels of mathematics anxiety (Hembree, 1990) it seems reasonable to assume that others have ruled out teaching as a career because of the severity of their phobic responses to mathematics. There is anecdotal evidence amongst academics of pre-service primary school teachers vomiting the night before mathematics tutorials due to their intense anxiety, and there is evidence to suggest that mathematically anxious primary teachers may transmit such anxiety to their students (Wood, 1988). That a single area of the curriculum could have such a negative psychological, and somatic, impact on people suggests that its radical modification deserves serious consideration.

One fundamental problem with mathematics may be that it is largely unnatural. It has a mythology about it that resists pragmatic analysis. Many of the arguments about the utility of mathematics mimic those of supporters of Latin: preserving intellectual rigour; resisting efforts to 'dumb down' the curriculum; training the mind, and so on, essentially what Ernest (1991) characterises as the *old humanists* position. However there is clear evidence that particular personality traits predispose some people toward, and perhaps improve their ability with, mathematics (Head, 1981). This might be exemplified by the overly visual and abstract nature of mathematics privileging visual learners over tactile or auditory learners. However, if certain segments of the population are advantaged in such a broad social benchmark as mathematics performance, then equity once again becomes an issue.

1.2.8 Rethinking mathematics education

My investigations that started out focussing on how to improve mathematics teaching have ultimately led me to conclude that mathematics teachers' roles may be impossible. If they have not been traumatised by mathematics themselves, then there is a good chance that many of their colleagues and students have been. Even amongst those who have not been harmed by mathematics, there are distinct difficulties associated with certain learning and cognitive styles being better suited than others to coping with mathematics, so that nearly all classrooms are divided into those who can and those who cannot do mathematics.

However, much school mathematics may only be relevant to a small percentage of all students. So perhaps what we need instead is numeracy *qua* dispositions rather than proficiency in mathematical techniques (Perso, 2006). There is little research that looks at mathematics anxiety in the first few years of schooling, although there is evidence that this is when it may first manifest itself (Chiu & Henry, 1990 – in Ma, 1999).

Specialisation at university would be a far simpler proposition when students have already made significant decisions about their future pathways, rather than imposing high levels of mathematics on all students just in case they need it. This has traditionally happened successfully in many other areas of specialisation such as medicine, law, mechanics, philosophy, and archaeology. Some universities delay specialisation even further by offering only postgraduate study options for gaining entry to certain professions.

Arguably the tertiary sector has pushed the responsibility for teaching students down to the primary and secondary years of schooling. This old humanist manoeuvre allows them the freedom to criticise schools for poor performance while using their own filtering mechanisms to accept only the most academically talented students. Some suggest that if universities practised what they preached about teaching all students well, there would be no need for the use of secondary school results to filter out those expected to fail at university (Teese, 2009). That is, universities appear to adopt a *do as I say, not as I do* approach to education.

If teachers, schools, and teacher educators were able to wrestle back control of their domain, then it might be possible to implement an approach to mathematics teaching that empowers students to become appropriately mathematically skilled members of society, whatever their employment destination, by equipping them with the kinds of mathematical tools they will need to avoid succumbing to the manipulations of unscrupulous advertisers, politicians, or con artists. I believe we want a society of people who can fend for themselves in shops, work places, and polling booths rather than a society full of people who can integrate by parts. The final chapter explores some of the duty of care issues that arise from mathematics as a source of psychological harm, and proposes a different approach that would see current mathematics replaced by a focus on functional, financial, and citizenship numeracies as well as accommodating the playful and fun aspects of mathematics as part of aesthetic mathematics.

1.3 *Background and Context*

This section provides additional details on the context of this research. It provides information on the broader project which the teacher participants were part of, and some information on my personal background.

1.3.1 The Task Type and Mathematics Learning project

The research reported here took place within the context of working with teachers who were participating in an Australian Research Council funded research and professional development study, the Task Type and Mathematics Learning (TTML) project. The TTML project worked with approximately 50 teachers from 17 schools in Victoria who were interested in improving their mathematics teaching.

The TTML project was investigating the best ways to use different types of mathematics tasks in helping schools to face the challenges of engaging students in learning mathematics, and as a result, help to stem the serious decline in the number of students entering university level mathematics courses.

The project focused on four types of mathematical tasks, with the main research questions being: What are the characteristics of learning that is fostered by each of the task types; what constraints are experienced by teachers; and what are the most appropriate pedagogies?

To answer these questions the team worked with middle years' teachers (Years 5 to 8) from volunteer clusters of schools. There were professional development components to the project as well as data collection, and the intention was to create optimal conditions for the successful implementation of each task type by ensuring that teachers had access to high quality task exemplars and by supporting teachers on associated pedagogies. The hope was to initiate a self sustaining process of task creation and use.

The four types tasks identified were:

Type 1: Where the teacher used a model, example, or explanation that elaborated or exemplified the mathematics.

Type 2: Where the teacher situated the mathematics within a contextualised practical problem to engage students while having an explicitly mathematical motive.

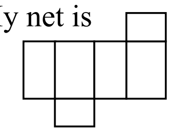
Type 3: Where students investigated specific mathematical content through open-ended tasks.

Type 4: Interdisciplinary investigations.

Some examples of each of these types are given below.

An example of type 1:

The following is a set of statements that are put onto cards, with the intention that students match up those that refer to the same shape. For example, one set of these cards is as follows:

I have 12 edges	I have 8 faces and 8 vertices	I am a rectangular prism	My net is 

There are five such sets. The idea with these cards is that students sort them into groups, and in the process come to see them as different properties of the same object. The task is low in risk for students, and prompts communication about the learning. It can be easily extended to build a lesson around the key ideas of linking the language and properties of 3D objects.

Some examples of type 2 tasks are:

- Mike from Tasmania, wrote all of the numbers from 1 to one million. In so doing, how many digits did he write altogether?

- You have won a prize. Your prize can be either: 1 metre of $2 coins; one square metre of five-cent pieces; one litre of 20-cent pieces; or 1 kg of $1 coins. Which would you choose?
- BP advertises that “5% off BP petrol beats 4 cents off a litre.” When is this true?

Type 3 examples:

- A group of 7 people went fishing. The mean number of fish caught was 7, the median was 6 and the mode was 5. How many fish might each of the people have caught?
- A closed box (rectangular prism) has a surface area of 94 sq cm. What might be the dimensions of the box?
- What might be the missing digits?

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A type 4 example:

- Different foods contain different amounts of energy, and these are often shown on the packaging. Do some research either at the school canteen, school vending machines, or at local shops to find out what is the most number of kilojoules you could get in a single food for $5. What is the least energy you could buy for the same amount? Write up a report with some graphs of food types and how much value for money you get in terms of energy per dollar. Explain how you have worked out your answers. Also comment on how useful this approach is to having a healthy diet. Make some recommendations about the healthiest meal you can buy for under $10, with the lowest energy content.

Each of the three chief investigators took responsibility for one cluster, and provided support to them through active teacher professional learning and the creation or sourcing of respective tasks matching the teachers’ curriculum, whilst overseeing the data collection at each phase. Teachers were asked to set a goal of using at least one lesson per week using classroom tasks of the relevant type(s) for that phase, and no support was offered on tasks of the other types. The eventual goal was for teachers to generate their own tasks.

There were many teacher development meetings (at least two per term) where further data collection occurred and the teacher learning focused on the nature of the respective task type, associated pedagogies, ways of addressing key constraints, and student assessment. The professional learning sessions also addressed the theoretical rationale for, and usage of, the respective task types, the expected student responses, the associated pedagogies, and the processes for constructing such tasks and matching them to the *Victorian Education Learning Standards*. In addition to the teacher meetings and teacher conferences the project involved classroom observations, student surveys, teacher surveys, student interviews, teacher interviews, and teacher sorting tasks.

A range of data were collected, including reports on teacher learning sessions, analysis of lesson sequences, surveys and observations of teachers, and a large scale student survey.

The research findings can be summarised as follows.

With respect to the tasks (Sullivan, Clarke, & Clarke, 2009):

- Teachers were able to use all three types of tasks in their planning and teaching.
- Converting tasks to lessons is harder than is generally thought, and teachers need support in doing this.
- Teachers' mathematical knowledge is more than adequate for many topics.
- Teachers are able to use all three types of tasks in their planning and teaching.

With respect to teachers:

- There are many ways of teaching well. For example, there were many observations of excellent instances of teaching based on: a detailed knowledge of what the students were doing; allowing students real choice; clear interactive explanations; and interesting applications of relevant mathematics. In all cases the excellent teaching was active.

With respect to the need for variety (Sullivan, Clarke, Clarke, & O'Shea, 2009):

- Different students have preferences for different types of tasks in both their enjoyment and their learning potential, and this applies both to students who identify as mathematically strong and those who identify as weak.
- A good program would utilise all three types of tasks (and possibly others).

- Some students like a focus on content topics and others a focus on context of learning.
- Within class variations in students' confidence in and enjoyment of mathematics generally, and the particular types of tasks they liked and learned from, were much greater than between class variations, and teachers need to find a way to cater for this diversity.

The three types of tasks were designed to represent potentially successful task types. The goals were to describe in detail how the tasks respectively contributed to mathematics learning, the features of successful exemplars of each type, constraints teachers experienced, and which teacher actions best supported students' learning (Clarke & Roche, 2009). Interestingly, the fourth task type proved too difficult to implement even within the supportive environment of the TTML project.

1.3.2 My background and personal reflections

From a personal perspective, my interest in this area of research stemmed from my own teaching practice and the difficulties I had observed and experienced in bringing about effective changes to mathematics education. I started teaching secondary mathematics in 1990, but left teaching three times for other careers due to changes in educational policy. As a result I have gone from being a mathematics/science teacher at a private school, to research associate/lecturer at a university, to mathematics/IT/physics teacher in a government school, to database/web site programmer in industry, back into a government school classroom, and then into a management role within a harm prevention charity. Thus I have a reasonable firsthand understanding of the demands of working within both educational and non-educational settings, which I believe has helped to inform my sense of what is reasonable to expect of workers.

Throughout my teaching career I had found mathematics one of the most challenging, yet least fulfilling areas to teach. In my experience, those students who exhibited mathematical confidence and/or aptitude were in the minority with most students coming to mathematics either grudgingly or with indifference. A large number of students struggled with the material covered, and it was difficult to connect many of the topics covered to students' lives in any authentic/meaningful way.

My own efforts at utilising outdoor or kinaesthetic based activities to convey mathematics, or use of the gems contained in the Mathematics Curriculum and Teaching Program books (Lovitt & Clarke, 1985), were ultimately unsustainable in a hostile faculty environment where skills tests and textbook knowledge were the benchmarks against which one's students were measured. Ultimately I found mathematics to be couched in typically bland, artificial contexts, making it almost inevitable that the majority of students would fail to see any relevance to themselves, and there was little I could do to change this within the constraints of the school mathematics curriculum and culture.

Nevertheless my interest in engaging students with mathematics persisted. My first foray into academia involved looking at engagement factors for students in their selection of senior secondary mathematics (Toomey & O'Donovan, 1997). During that time I also worked as a research associate on an Australian Research Council (ARC) funded national project exploring such factors more broadly (Malone, Cavanagh, Webster, Dekkers, Toomey, O'Donovan, & Elliott, 1997).

More recently, as a practising secondary teacher, it had been of particular concern to me that many students were disenfranchised by school generally, resulting in poor prospects for themselves, increased stress for their teachers from behavioural problems, and adverse impacts on their peers' learning opportunities. Or to paraphrase Fred Dagg – disengaged students appear to be fools to themselves and a burden to others (Clarke, 1981). For disengaged students, mathematics was often the 'pin-up subject' of what it is they hated about school.

So when the formation of the Victorian Institute of Teaching (VIT) brought various bureaucratic pressures to bear on teachers, including a minimum number of professional development hours upon which registration was contingent, I took the opportunities afforded me by an arrangement between Monash University and a local cluster of schools to once again tilt, academically, at the mathematical disengagement windmill.

The transition from classroom teacher to researcher had been a slow and subtle one. I noticed how it was a process of enculturation, one of trying to capture the flavour of the new environment and of how the people who populated it viewed the world. The contrast between my teaching goggles and the kinds of arguments academics would make about teaching was stark at the beginning, but I found these boundaries faded with time and I sometimes wondered if I had lost something – other than naivety.

One contrast that remained reasonably fresh for me was the gulf between the theoretical and the practical. There did not seem to be any examples of ‘optimal teaching’ that could be showcased. Either there was an inherent impracticality about the various theories propounded or a distinct lack of their implementation. It seemed that what constituted success or failure within a classroom was ambiguous, and perhaps as much in the eye of the beholder as anything else. This was demonstrated nicely by Lerman (1990) in which the same videotaped teaching sequence was shown to a number of pre-service teachers. Their critiques of the teacher were almost diametrically opposed; half of the pre-service teachers commented that the teacher was too directive while the others commented that she was not directive enough. To the practising teacher in me, much analysis of that sort appeared far removed from the realities of the classroom where no two sessions were the same and detailed knowledge of each student took precedence over any underlying rules or guidelines. It would certainly require more than a few videotaped interactions to draw any meaningful conclusions about the teachers’ actions.

I believe that at base, students and teachers dealt in mathematical tasks rather than theories. Teachers find themselves in the pragmatic sphere of curriculum delivery, faced with a classroom full of students, a staffroom full of teachers, an office block full of principals and administrators, and an enveloping society full of parents, media, bureaucrats and politicians. There are some clear expectations that teachers face each class and each year, typically of the form; keep your class under control, teach them this curriculum, work out how well they each can do it, then write their reports. Beyond these basic expectations were a growing array of demands outside the scope of this research project.

Whether there really is an optimal form of teaching might better be judged by the outcomes of the teaching rather than conformity to one theory or other. In the cut and thrust of classroom and school life generally, there is little space, time or energy available for musing on less pragmatic issues. Photocopying the test for period 3 before the recess rush takes a priority over the many other competing thoughts that might be entertained. The richness of individual student’s thoughts, views and capacities may well register in a teacher's consciousness, but such notions are quickly driven out by more mundane, practical worries and demands.

From the students' perspective, for many, mathematical proficiency had come to be a source of embarrassment. From observations of my own classes, it was often 'uncool' for secondary students to be good at mathematics, and many students would actively avoid answering questions posed by the teacher so as not to expose themselves to ridicule by getting it right and being 'geeky'. This could remove one of the standard feedback mechanisms teachers relied on for gauging student understanding and engagement, thus increasing the pressure on teachers and broadening the gap between teacher and student. In a world where mathematics teachers were already perceived to be 'boffins' or 'geeks', this resistance to involvement amongst students served to further alienate them from the world of mathematics.

In a similar vein, seeking approval from teachers appeared to be less and less desirable to the students, being replaced instead by desiring acceptance from peers. Combining this with peer disdain at mathematical ability produced a situation for some students where there was much to be lost by contributing in class. These social pressures forced some students toward disengagement from the teacher and mathematics – not unlike the 'acting white' phenomenon in the United States where, for instance, the actor Wil Smith has related how he would hide school books in pizza boxes because of the anti-intellectual pressures that existed within his peer group. Such perceptions lock teachers into the role of external transmitters of knowledge because students resist efforts teachers might make to involve them in knowledge exploration and/or construction.

Mathematical language is another element I feel has contributed to student disengagement. Technical terminology is integrated into mathematics so that unfamiliar, formal language is part of the mathematics classroom culture, and if students are unfamiliar with the language, or are intimidated by formal discourse, they are less likely to engage in use of such terminology. While some technical language is important, and perhaps unavoidable, it seems unnecessary to inflict it everywhere – so "vertices" replacing "corners" when discussing basic shapes seems unhelpful. Use of this language identifies proficient practitioners and has come to be known as a form of 'geek speak', further isolating those students who use correct terminology from their broader peer group.

In my experience mathematics has tended to be taught in a binary manner where answers were either right or wrong, and either conformed to the 'correct' process or did not. This makes a stark contrast with subjects such as English where there were no right or wrong answers per se, and few clearly defined processes. English teachers often spend their time attempting to develop generic skills, revisited each year and built up over time. Mathematics teachers on the other hand tended to deliver distinctly different detailed processes which may or may not reinforce and mutually support each other. Each year of mathematics covered new procedural territory, whereas in English essentially the same processes were applied to increasingly sophisticated settings. Also, English often incorporated current events, making it contemporaneous to students' lives, whereas mathematics mostly posed procedural problems couched in either totally abstract, or obviously contrived contexts. Contrasting mathematics with English in this way serves to clarify, to me at least, why students may be disengaging from mathematics, and helped me to understand a comment by Wink (2005) that "if it doesn't matter to learners, it doesn't matter" (p.18). It also underpinned my interest in exploring how to make mathematics more relevant and interesting to students, and the necessity of engaging mathematics teachers in altering their approach to mathematical pedagogy for this to be realised. These concerns and interests underlie the starting point for this research wherein I hoped to help teachers to be better able to help students.

1.4 *Research questions*

This section provides an overview of the initial directions of the research I embarked upon and detailing the questions that drove it.

1.4.1 Initial research questions

Obviously not everything can be explored in one research project, and some things are simply not readily amenable to rigorous investigation. There were many potentially fruitful avenues for seeking to understand better why students were not enjoying mathematics and why enrolments in mathematically based tertiary courses were dropping. But that this disengagement and decline was symptomatic of a mismatch between current mathematical classrooms and the current generation of students appeared to be a reasonable starting point. Two obvious factors were the curriculum and accompanying pedagogy. Whilst changes to the curriculum might prove beneficial any such changes would have to first be implemented by teachers. And if the pedagogy of those teachers was of any importance, then the gains to be made by curriculum change would not eventuate. So the most immediately fruitful area of investigation would be to explore teachers' willingness to adjust their pedagogical practices. This gave rise to the following questions that initially guided this research:

- Could a data collection tool facilitate teachers' reflection on their practice?
- How willing were teachers to embrace a new approach to analysing their pedagogical practice?
- What kinds of reflection did teachers engage in when analysing their practice?
- What learnings, if any, did the teachers derive from the overall experience?
- How could the tool be improved to better assist teachers reflect on their practice?

However, as the research bore fruit in addressing these questions, I formed the opinion that teachers were not the major bottleneck, and a further set of questions arose which guided the subsequent investigation. These were:

- What constitutes reasonable expectations of teachers?
- How does the teachers' mathematical confidence impact on teaching?
- How realistic are current expectations on mathematics teachers?
- Are there particular groups of students who cannot access opportunities that success at mathematics create, not due to a lack of ability, but due to chance cultural factors?
- Can mathematics in its current form be justified as a school subject?

CHAPTER 2

The initial goal: The Real Time Feedback System

> "A lot of things have happened in this century and most of them plug into walls"
> (*Father John Culkin*)

2.1 *Attempting to help teachers reflect*

As mentioned previously this thesis began with a reasonably tight set of research questions that focussed on facilitating teacher reflectivity through the use of a technological tool that was intended to assist teachers to become researchers of their own practice in order that they could refine and improve it. This chapter outlines the social context that motivated this approach wherein school mathematics is described as being in crisis, and goes on to review literature relating to teacher professional development, influences on teachers' practice including their beliefs, and issues around how best to tackle teacher improvement.

This chapter also deals with methodological issues associated with this approach and provides some details on the development of the Real Time Feedback System tool. While the process of investigating these questions ultimately led me to focus on a set of broader concerns, this section provides details on the initial approach that culminated in that change of direction. Due to the change in focus, only a rudimentary description of the development of the software is provided here, with all documented Active Server Pages, data dictionary, stored procedures, triggers, and all database files appended on the enclosed CD-ROM for interested readers.

2.1.1 A crisis in school mathematics education

Many commentators have identified a crisis in mathematics education. Low student engagement, reduced enrolments into related tertiary courses, and subsequent shortage of suitably skilled workers are causes for concern as industries transition into the knowledge economy (Drucker, 1993). Students who find mathematics at school hard and boring, get poor grades, or dislike their teacher, tend to reject mathematics outright or enrol but remain uninterested (Department of Education, Science and Training, 2006). This may account for the 20% drop in enrolments in senior secondary mathematics across Australia from 1990 to 1999 while there was a 92% increase of enrolments in low level mathematics for the same time period (Dekkers & Malone, 2000). Decreases in intermediate level enrolments also continued to occur from 2000 to 2004 (Forgasz, 2005).

Some have attributed a pragmatic materialism to members of Generation Y who, whilst largely interested in financial security and happy family life, see the pursuit of specialised tertiary education as inflexible and not providing the adaptability they believe they will need in a world devoid of job security (Saulwick Muller Social Research, 2006). Since much secondary level mathematics lacks any obvious day-to-day applicability, such a pragmatic attitude may be a factor in students failing to appreciate the value and utility of mathematics. From a sales metaphor perspective, it might be that post-compulsory mathematics is not a product that many student consumers see as something they want or need. The link between mathematical success and career options is rarely explicit in a mathematics classroom, so high school students – and their teachers – may remain largely unaware of the growing demand for mathematically proficient workers.

It is pertinent, then, to explore whether there are identifiably better ways to teach mathematics, and whether there are particular approaches which are more or less successful in conveying mathematical concepts and/or engaging students. And importantly, how might teachers be encouraged or persuaded to adjust their approach to the teaching of mathematics.

As outlined in Chapter 1, this research was part of a larger Australian Research Council funded project, Task Types and Mathematical Learning (TTML), exploring mathematical task types and their use in engaging students. The TTML project argued that teachers use broad curriculum goals and specific advice to plan learning experiences for their students, and while acknowledging that teaching is essentially about relationships between teachers and individual students, the proposition was that these relationships are mediated by learning experiences. The challenge for teachers was to engage students in activities that fostered learning, and the media for interaction was thought to be through the tasks and associated activity. The learning experiences were based on the tasks, and so the better the task, the better the relationship, and the better or more appropriately the task was used, the better the learning.

The TTML project had a dual purpose in terms of attempting to understand modes of curriculum delivery that maximised engagement as well as providing professional development for teachers involved in the project. Concomitant to these was the desire to gain insights into how best to convince teachers to adopt different, more effective approaches to teaching mathematics. Thus the initial purpose of this thesis to attempt to help teachers to become more reflective through the use of a technological aid was a good fit with the aims of the TTML project, and was complementary to what the teachers participating in the that project hoped to gain.

2.1.2 Initial research questions

As outlined previously, the initial set of research questions sought to narrow the focus of this study to investigating teachers' willingness and capacity to reflect on their pedagogical practice. The rationale for this was that the apparent student disengagement from mathematics arose from either the curriculum or the accompanying pedagogy. Whilst curriculum innovation might be useful, any such changes to the curriculum would still need to be interpreted and implemented by teachers, so that if teacher practice was a major factor in student disengagement, then any progress that might be expected from curriculum change could fall at the first hurdle. In other words, if teaching and attitudes to teaching were the bottleneck, no amount of curricular change would help. For this reason I initially chose to explore teachers' willingness to reflect on their pedagogical practices, giving rise to the following set of research questions:

- Could a data collection tool be used to collect students' views and facilitate teachers' reflection on their practice?
- How willing were teachers to embrace a new approach to analysing their pedagogical practice?
- What kinds of reflection did teachers engage in when analysing their practice?

- What learnings, if any, did the teachers derive from the overall experience?
- How could the tool be improved to better assist teachers reflect on their practice?

The original intent was to focus on the circumstances under which teachers might be prompted to reflect on their practice, to investigate the utility of a classroom tool in assisting with reflection, and to explore any teacher learning that occurred. To achieve this it was important to explore existing literature in the field of teacher learning.

2.2 *A literature review of factors influencing teachers' learning*

This section seeks to provide an overview of some of the literature relating to factors that influence teaching and teachers' learning. It canvasses the view that much traditional educational research has adversely impacted upon teacher education in a number of ways. One such impact has been the fostering of an approach to teacher education that places little, if any, emphasis on subject content knowledge (Shulman, 1986). It is worth noting that one of the purposes of the TTML project was to explicitly help teachers improve their content knowledge of mathematics, an aim made especially pertinent by the claim of shortages of well qualified mathematics teachers (Committee for the Review of Teaching and Teacher Education, 2003).

Another consequence for teaching that appeared to flow from educational research was teacher disempowerment through the 'rhetoric of conclusions'. This contributed to teachers needing to build secret and safe places for themselves within what Connelly and Clandinin (1995) referred to as the 'landscape of teaching', effectively insulating themselves from administrative demands based on theoretical abstractions that had limited use in the cut and thrust of the classroom. The tension between teaching and research was also particularly apparent within the exploration of teachers' beliefs in which the lines of enquiry often conclude that teachers' actions are inconsistent with their stated beliefs. However, these analyses may not only have been unhelpful in bridging the gap between researchers and teachers, but also might be logically untenable. Leatham (2006) has offered an alternative approach by positing teachers as 'sensible beings', and instead viewing them as adapting to their environment (or landscape).

The value of such an approach was underscored by the kinds of influences teachers experience as identified by Sullivan and Leder (1992). There, instead of finding the most influential factors to be those typically identified elsewhere in the literature such as teachers' own experience of schooling, moving from being a student to becoming a teacher, enculturation, and familiarity with curriculum content, rather they found the classroom environment to be the most significant influence on teaching, and notably students' responses to their teacher.

Lastly, this section considers a number of authors' suggestions of how teacher education and professional development might be changed in order to address the various factors identified as problematic in the literature.

2.2.1 Teachers' content knowledge

The body of mathematics teaching research is diverse, and many issues have been identified. One fundamental concern is the mathematical knowledge of teachers. For instance Shulman (1986) harked back to American State Board elementary school teacher examinations circa 1875 and noted that 90-95% of the questions on those tests revolved around assessing prospective teachers' knowledge of direct and indirect subject content. The remaining 5-10% of the questions involved knowledge of pedagogical theory and practice. He contrasted this historical situation with modern day teacher education wherein the emphasis is reversed. Shulman (1986) claimed that content knowledge is now assumed, and largely ignored, whereas a major emphasis is placed on teaching theories and methods.

Shulman (1986) claimed that decision makers had justified such policy shifts by citing research into teacher effectiveness. However, such research has typically excluded subject content from consideration and instead sought to "identify those patterns of teacher behaviour that accounted for improved academic performance among pupils" (Shulman, 1986, p.6). Shulman (1986) refers to this research (and policy) gap as the 'missing paradigm' problem.

It would seem that this shift toward teaching processes and away from content knowledge is unique to our times. Shulman (1986) briefly surveys the history of academia and universities to find that from Aristotle to Medieval times, and on into the late 19th century, the defining characteristic of teachers was their mastery of their subject areas. In other words, content, not process, was the critical factor.

Shulman (1986) points out that he does not wish to dismiss or denigrate pedagogical process knowledge, but rather to strike a balance between the importance of knowing both how to teach and what to teach. His central concerns are how expert students become novice teachers, how teachers convert their subject knowledge into a form digestible by their students, and how teachers overcome the inevitable content flaws in text books and other resources.

He goes on to distinguish between three categories of content knowledge; i) subject matter content ii) pedagogical content and iii) curricula content. The first category, subject content, relies on knowing *that* something is the case, *why* it is the case, and how important it is to the subject being taught to emphasise that it be the case. The second, pedagogical content, relates to how best to teach the type i) material. This involves knowledge of helpful analogies, examples, mnemonics etc. as well as an awareness of any pitfalls or difficulties students are likely to encounter in trying to grasp the concepts in hand. The third category, curricula content, appears to have considerable overlap with type ii), but is perhaps more broadly positioned. Shulman (1986) describes it as knowledge of the various materials and resources available to the teacher, which to use, when, and in what doses. He goes so far as to make a direct comparison with a doctor who would be expected to know the full range of treatments available as well as the advantages and disadvantages of each. This kind of content knowledge also incorporates teachers being aware, where relevant, of the other subject matter students are exploring in other classes, and how it relates to the material they are covering in their own class. Similarly, teachers should know of the previous and next year's content in order to situate their own subject matter appropriately.

Shulman (1986) argues that having such expectations of professional teachers could form the basis of teacher competence examinations which would measure depth of knowledge across his three content knowledge categories. These would pose questions about typical areas of student misunderstanding on specific content topics and how best to ameliorate them. The intention would be to distinguish – in pedagogically significant ways – between a person who has majored in a particular area of study, and one who is to teach in that area. Such an exam "would be much tougher than any current examination for teachers" (Shulman 1986, p.10).

According to Shulman (1986) prospective teachers are predominantly taught lists of research based propositions such as five step lesson plans (e.g., engage, explore, explain, elaborate, evaluate), and that longer wait times increase cognitive processing, . The disconnected nature of these propositions makes them difficult to remember and implement, so he proposes three broad categories that they fall into; *principles, maxims,* and *norms*. *Principles* arise from empirical research directing optimal practice, for example, structured turn taking while reading instead of random turn taking produces greatest improvements. *Maxims* are less likely to be backed by research, but rather represent teaching wisdom in the form of useful tips such as never smiling before Christmas (a Northern Hemisphere version of being firm with classes for the first term), or always saying a student's name when questioning them. *Norms* stem from value based guidelines which may have a philosophical or ethical foundation, for example, not embarrassing students in front of their peers (Shulman, 1986).

However, for Shulman (1986), even these categories do not provide a useful enough framework for teachers. In his view they are still not in a form sufficiently accessible or memorable, and so he suggests that a case based method be employed instead. This would help to contextualise the propositions, maxims or norms and thereby make them eminently more memorable. A classroom event or incident would only become a case if it clearly demonstrates the larger theoretical category it is felt to exemplify. Such cases could then be divided into three categories that parallels the previous propositional categories. These three types of cases would be *prototypes, precedents,* and *parables*. *Prototype* cases would demonstrate theoretical principles, *precedent* cases would demonstrate maxims in action and *parable* cases would demonstrate norms.

Shulman (1986) proposes that a further kind of meta-knowledge is also required by teachers. This knowledge transcends the three content knowledge types, whether propositional or case based, and is called *strategic* knowledge, or *judgement*. *Judgement* is required when prototypes, precedents or parables suggest conflicting courses of action, and allows teachers to choose the most appropriate way forward. This reinforces the general nature of propositions, acting as guidelines for teachers rather than dictating specific pedagogical practices. Ultimately it is the teachers' professional judgement that must be relied upon to implement propositions successfully; taking propositions or prototypes figuratively rather than literally.

Shulman's (1986) suggestion that teacher education has been adversely impacted by the inherent limitations of research is an interesting one: that the necessarily narrowed focus of educational researchers could impact upon the field so dramatically as to virtually eliminate a category of knowledge/competency and produce Shulman's (1986) missing paradigm problem. However, this may not be the only perspective missing. While Shulman (1986) is at pains to re-establish a balance between teacher knowledge and teacher practice within teacher education (which would certainly bring about a more comprehensive approach) there is at least one other relevant area which is being left out of the picture – how teachers experience schools as workplaces.

2.2.2 Inhabitants of a Professional Knowledge Landscape

Wilber (1996) sought to provide a comprehensive framework that eliminates the kinds of conceptual gaps that Shulman (1986) has highlighted. Wilber (1996) identifies four broad categories of reality representing the interior and exterior aspects of the individual and the collective, summarised below in Table 2.1.

Table 2.1: Table of quadrants adapted from Wilber (1996, p.107)

	Internal	**External**
Individual	Personal thoughts, Knowledge, Beliefs "I"	Observed behaviour, Pedagogical practice "It"
Collective	Cultural experiences, Shared belief, Schools as workplaces "We"	Social Systems/ Organisations, the School community "Its"

In this framework, pedagogical practice sits within the external-individual quadrant, where a teacher's personal actions can be observed. Shulman (1986) is calling for the emphasis to be placed on the internal-individual quadrant, that is on what a teacher knows and how they use that to direct their external-individual activities. Also inhabiting these two quadrants is the research dealing with teacher beliefs. Here the attempt is to explain the observable external actions of teachers by identifying, or inferring, their internal beliefs. Whilst all are couched within the schooling system (external-collective), none of these approaches deals with the internal-collective, or cultural, aspects of working in a school.

On this account, a teacher is an amalgam of their beliefs and knowledge, the way they teach and behave, and how they experience/contribute to the school culture. Connelly and Clandinin (1995) set out a metaphorical framework to explore the cultural experiences of teachers, casting them as inhabiting a professional knowledge landscape set between teachers' experience of theory and practice in order to help "contextualize research-based understandings of teachers' personal practical knowledge" (Connelly & Clandinin, 1995, p.4). This landscape is both an intellectual and moral one, spanning the classroom and other professional, communal spaces, populated by a variety of people, places and things. Interestingly, Connelly & Clandinin (1995) report teachers feeling disturbed by being in this landscape.

Part of this disturbed feeling is attributed to the dilemmas teachers face, notably the insoluble epistemological dilemma between theory and practice. Outside of the classroom exists the research community and policy makers, each feeding into the landscape in order to effect changes in teacher practice via theory. Meanwhile teachers are expected not only to be expert practitioners, but also to do so in a theoretically reflexive way. Each of theory and practice make conflicting claims on both researcher and teachers. Connelly and Clandinin (1995) argue that glossing over the difficulty of researchers being more practical and teachers using theory better has been harmful to dealing with the problems inherent in school reform, teacher education and professionalism, and served only to further alienate and disturb teachers by failing to acknowledge and lend credibility to the difficulties they perceive.

Connelly and Clandinin (1995) suggest that the dominance of the notion of theory based practice is so entrenched that it has taken on the qualities of a "sacred story" – one that is unconsciously part and parcel of the landscape and its occupants. And most of the theories and policies conveyed to teachers are stripped of their assumptions, limitations, and inquiry-based origins, instead being presented as sets of uncontroversial, established conclusions – effectively becoming what Schwab (1962) referred to as the "rhetoric of conclusions". As a result, such stripped down knowledge claims are neither theoretical nor practical, and the language used to discuss them by teachers and administrators is similarly abstract. Thus "abstract diagrams, assessment plans, factors, school improvement plans, schemata, forces, research conclusions, research prescriptions, policy prescriptions, and so forth, fill the landscape" (Connelly & Clandinin 1995, p.10).

Another feature of the rhetoric of conclusions is that the content becomes sacred to the extent that there is no provision for debate or modification. The knowledge has been removed from its human origins and elevated to a privileged status of 'given'. To challenge such material is to step out of the intellectual sphere and into the political – to move from challenging the concepts themselves to challenging the authority promulgating them.

Further, because of the power relationship built into the rhetoric of conclusions it is implicit that the concepts being injected into the landscape should be acted on. They are not value neutral abstractions, but instead take on the tone of moral imperatives that should be known and acted on by teachers. Connelly and Clandinin (1995) suggest that the landscape is so full of such – often conflicting – "moral admonitions", that administrators are forced to issue vision statements to help further shape and provide moral unification.

Inside the classroom is a different space for Connelly and Clandinin (1995). It is a private, safe place where teachers are able to practice free from scrutiny. The lived stories of practice are essentially secret ones, shared only with other teachers in other safe spaces, such as after school gatherings away from the school. In describing the secret nature of classrooms Connelly and Clandinin (1995) do not advocate secrecy per se, noting various abuses that can occur in secret spaces, but acknowledge that "teaching is a secret enterprise and depends for its success on the maintenance of a safe place for those secret acts of teaching to occur" (p.13). As a result teachers become wary of sharing their experiences with non-teachers further reducing the chance that they might recognise themselves in the accounts put forward by academics.

Connelly and Clandinin (1995) view teachers from a narrative perspective: living; telling; and retelling stories, being characters in their own teaching stories of which they are the authors. They see the staffroom as an increasingly unsafe place for teachers to share their stories, and that teachers need to be able to take part in conversations where stories are told, reflected back, retold and relived in order to open the possibility of awakenings, insights, and transformations. Outside of the classroom is inhospitable for such story telling, being so dominated by the rhetoric of conclusions. If teachers represent their knowledge in this part of the landscape by telling their secret stories of classroom happenings they are portrayed as tentative, narrow, and non-expert. Given their accountability to those others who inhabit this space they are forced to resort to “cover stories” instead, using the abstract language of this out-of-classroom part of the landscape and talking instead about lesson plans, strategies and assessment techniques.

The rhetoric of conclusions is not unlike popular science programs wherein the technical difficulties of a complex field are diluted or smoothed out to present digestible content for an interested public. However the pre-digested knowledge is often not representative of the actual science, and not particularly useful to the audience. It may just serve to build an aura of obfuscation around science and further alienate the public from the realities of scientific research.

In education the problem is exacerbated further. In professions such as science, medicine, law, architecture, engineering, there are empirical outcomes – formulas that work, patients that get better or worse, cases that are won or lost, buildings and bridges that stay up or collapse – whereas in education there is little empirical evidence available. Students may or may not know something, but how we establish this is highly problematic. No two students are the same, no two schools are the same, and no two classrooms are the same – even the same class with the same teacher can be radically different on different days. Such variability renders decision making nigh impossible without generalisations – hence the obvious appeal of the rhetoric of conclusions for policy makers who might otherwise be unable to function at all. Not everyone has the time or skills to read the source articles behind the conclusions. Nor would it be particularly helpful to the practitioner to do so – what good is research if conclusions cannot be reliably drawn from it? But it could also be argued that when research is largely speculative, of questionable veracity, or limited applicability that such conclusions should come with disclaimers.

Further compounding these complexities is the possibility that while teachers may hold, or claim to hold, certain progressive beliefs about teaching, their actions may contradict these beliefs. Considerable work has been done in this area, some of which is reviewed next.

2.2.3 Teachers' beliefs

One significant area of research within education concerns teachers' beliefs, how they drive teachers' practice, and how teachers' observed actions frequently contradict their stated beliefs (Thompson, 1984; Raymond, 1997). Lerman (2002) argues that an awareness of these discrepancies would motivate a teacher to attempt to change their practice. This is particularly relevant to this thesis since if teachers are to implement a new approach to teaching it would be necessary that their belief system be able to accommodate such a change.

However, Leatham (2006) identifies two potentially flawed assumptions common to a number of articles that explore mathematics teachers' beliefs; i) that teachers can easily state what their beliefs are, and ii) that the meanings researchers take from these statements accurately reflect what the teachers actually meant. Leatham (2006) points out that despite these two points of possible error, researchers have gone on to claim that teachers are engaging in behaviours that are inconsistent with their own beliefs, and that teachers hold inconsistent sets of beliefs. Leatham (2006) argues that such conclusions do a disservice to both teachers and researchers, and offers an alternative framework for researchers to work from, a 'sensible system of belief', one in which teachers are assumed to be "inherently sensible rather than inconsistent beings" (p. 92).

Leatham's (2006) framework proposes that beliefs influence action regardless of the actor's ability to express or even be aware of their beliefs. He suggests that researchers can only draw plausible inferences about these underlying beliefs when they have access to a number of sources with which to triangulate such inferences. He essentially argues that to make a believable inference about teacher's underlying beliefs one requires a variety of evidence, not just a teacher's statement on a questionnaire or in an interview.

Using multiple sources of evidence to form convincing interpretation of underlying beliefs parallels Leatham's (2006) own stated beliefs about the nature of beliefs (or metabeliefs). He quotes Thagard's (2000) analogy of beliefs being like rafts floating at sea. In this analogy, beliefs are justified by forming mutually supportive clusters, as opposed to being arranged hierarchically as they would be in a house analogy where beliefs are justified by starting from foundational 'truths' and building up other beliefs using logical cement. By contrast the raft analogy provides justification by adjusting surrounding beliefs until a coherent, mutually supporting raft of belief obtains. The beliefs are adjusted or 'tweaked' until it all makes sense to the believer.

The ways in which a raft can be tweaked are manifold: first by adjusting the importance or strength of beliefs; second by changing the relationships and links between them; and third by modifying how they are grouped or clustered.

Leatham (2006) uses Rokeach's (1968) notion of connectedness to capture the importance or strength of beliefs. The more central or peripheral a belief is determines its importance and hence its resistance to change. Leatham (2006) focuses on Rokeach's (1968) four defining criteria of connectedness. These are, from most to least central: existential (pertaining to our place in reality); shared (held in agreement with others); derived (stemming from sources of authority); and taste (most peripheral and easiest to change).

In addition to Rokeach's (1968) connectedness, Leatham (2006) uses Green's (1971) quasi-logical relationships between beliefs as a second dimension of his belief analysis. This dimension identifies beliefs as primary or derivative based upon a logical relationship that is felt to exist between two (or more) beliefs. For instance, the belief that students should not use calculators may be logically derived from a primary belief that students should know their times table. Leatham (2006) points out that even though a belief may be primary in this dimension, it is still possible that the derivative beliefs are held more strongly by the person than the corresponding primary beliefs. This also reinforces a weakness of the house analogy compared to the raft analogy, given that he house analogy forces primary (or foundational) beliefs to be held more strongly than derived ones.

The third dimension also comes from Green (1971) and involves a compartmentalisation of belief clusters. This grouping of beliefs entails that what may appear as contradictory beliefs to an external observer will not be considered to be contradictory by the person holding the beliefs. This creates room for the existence of contextual beliefs wherein something may be believed in one set of circumstances but not another – the proverbial 'exceptions to the rule'. It is this dimension in particular that allows Leatham (2006) the latitude to claim that there is no such thing as contradiction in a sensible system approach to teacher beliefs. Teachers who seem to hold contradictory beliefs have already made sense of the situation and it is up to the researcher to find out how they have done so, regardless of how irrational or unjustified it may seem; "our incredulity does not diminish another's coherence" (Leatham 2006, p.95).

Leatham (2006) goes on to present some examples of claimed inconsistencies from the literature and reinterprets them in terms of the sensible system approach. The first example from Raymond (1997) is explained as a matter of context – that the setting observed by the researcher was one in which the teacher gave preference to one cluster of beliefs (class management) over another cluster of beliefs (importance of group work). But, Leatham (2006) argues, this represented only one context where the teacher drew on her beliefs in this way, she may have prioritised otherwise (e.g., group work over class management) in a different context (such as in an interview, or with a different class), or her class management beliefs may be psychologically stronger (more central) than her beliefs about group work. In either case her beliefs about mathematics are not enough alone to adequately explain the observed behaviour and further information is required.

In his second example Leatham (2006) uses the notion of misinterpretation to preserve the teacher as a sensible being. In this example, drawn from Cooney (1985), a teacher is deemed inconsistent because of his claimed preference for problem solving, but lacking the use of problem solving in his practice. Leatham (2006) argues that the teacher may not have used the term 'problem solving' in the same way as the researcher, that the teacher may refer to any mathematical task as problem solving, not just the narrow range of activities the researcher was looking for. Once again further information would be needed to unpack the teacher's (assumed) underlying coherence.

A third example taken from Skott (2001) exemplifies this sensible system approach in action. Skott (2001) focussed on the explicitly stated priorities of a teacher rather than asking for their broader beliefs. He observed that much of the teacher's practice cohered with these priorities, but that at times there were elements that did not. For instance, a teacher might nominate encouraging accurate use of a technique as a priority, but be observed to praise some students' inaccurate efforts. Rather than tagging these actions as inconsistent Skott (2001) sought other ways to explain them that would make sense from the teacher's perspective. In doing so he was able to identify that on these occasions the teacher was acting on more fundamental, unstated, beliefs about students' feeling successful which over-ruled his other explicitly stated mathematical priorities.

Leatham (2006) concludes that researchers should be looking to build more comprehensive models of teachers' beliefs using teacher consistency as a guiding principle - looking not only for what teachers beliefs are, but also the ways in which they believe them, such as how strongly they are held, the links between them, and how they are grouped. He also claims that this has implications for teacher education in terms of aiming not just to replace or instil certain beliefs in student teachers, but also to make these desired beliefs the most sensible to follow in a coherent manner.

This approach places an emphasis on the practicalities of functioning in a classroom that is central to this thesis. If teachers are to alter their practice the end result must remain consistent with the practical demands of the classroom, otherwise either no enduring change will occur or teachers will be placed under additional pressures as they attempt to cope with the burden of impractical expectations.

2.2.4 Logical problems with teacher belief theory

If inconsistencies exist in this area, they do not reside with teachers alone. Beyond not giving teachers the benefit of the doubt, there are genuine logical problems lurking within research suggesting teachers are inconsistent. The flawed reasoning that seems to underpin some of this research raises issues that will be revisited in later chapters concerning unrealistic expectations of teachers within educational research. This problem flags a tendency within the literature to privilege theoretical constructs and to be critical of teachers for not living up to them. In the case of teacher belief theory there appears to be a fundamental problem stemming from the assumptions behind claims of teacher inconsistency being themselves logically inconsistent, or self contradictory.

This comes about as follows. The claim that a teacher is inconsistent entails that they were observed behaving in a manner at odds with their stated beliefs. The corollary to this is that researchers expect behaviour and stated beliefs to be in harmony, with any such expectation assuming behaviour is at least influenced by belief, if not wholly dependent upon underlying beliefs.

Indeed, without the stronger assumption that behaviour is wholly dependent upon belief, there can be no real teacher inconsistency to speak of, since unless the action arises directly from a belief, inconsistent actions might well result from some other internal or external non-belief related sources, such as heart rates or planetary alignments.

The very fact that researchers have considered it worthwhile to report on inconsistent behaviour implies this underlying strong assumption of beliefs not merely influencing, but actually directing actions. However, if behaviour is directed by underlying beliefs, then inconsistent teachers must also have underlying beliefs driving their inconsistent actions.

These underlying beliefs would be the 'true' – unstated – beliefs of the inconsistent teacher. Given these true beliefs are at odds with their stated beliefs, it would seem that (for some reason or other) these teachers must either be unaware of, or unwilling to share, their true beliefs. Connelly and Clandinin (1995) provide ample grounds to assume that teachers may well be unwilling to share their true beliefs, and so if teachers are unwilling, or unable, to state their true beliefs, it appears futile to have asked them what their beliefs were in the first place.

This set of assumptions entails Leatham's (2006) position that teachers cannot be inconsistent. At most they may be unable or unwilling to accurately state their own beliefs, but by force of the researchers' own assumptions there can be no inconsistencies between a teacher's behaviour and their 'true' beliefs, which poses the methodological problem of whether there is any value in asking teachers about their beliefs, and which leaves Leatham's (2006) sensible system as the only logically consistent position to adopt.

Even when teachers' stated beliefs are found to be consistent with their actions there may be logical problems. In light of the difficulties of gaining accurate statements from 'inconsistent' teachers, how confident can researchers be that 'consistent' teachers have managed to report their beliefs accurately? If it is possible for teachers to be demonstrably inconsistent, then it is possible for teachers to be accidentally consistent where unstated 'true' beliefs are the real source of behaviour, not those stated beliefs which also happen to cohere with observed behaviour. Ultimately there is unlikely to be any real way of knowing what has motivated a teacher to do anything.

The nature of belief is such a difficult area that it seems almost impossible to pin down anything concrete. An infinite number of possible interpretations can be constructed to explain any observed actions, and the amount of information required to get a credible understanding of what is going on for any particular teacher rapidly slides toward the psychoanalytical and personal narrative, both of which are fraught with their own sets of difficulties common to most human based qualitative research. In trying to use teacher beliefs as a basis for understanding their actions researchers run into the fog of interpretation, where any number of interpretations could be equally compelling.

The real difficulty seems to lie in predictive power, and it seems that much of the research to date has been focussed on a descriptive approach rather than an explanatory one (Cooney, 2001). It remains an open question as to whether these assumptions concerning beliefs have any merit; has any research actually demonstrated that teachers with particular beliefs do in fact behave in particular ways? Rokeach's (1968) studies represent an interesting approach in that they attempted to modify specific beliefs in subjects via hypnosis to ascertain their overall impact on belief structures. Perhaps such an approach could yield definitive answers in this regard for teacher belief research, but whether such research could be conducted ethically would be a matter of considerable debate. Without some stronger theoretical connection between teacher belief and teacher action it seems that descriptive studies are doomed to remain in a mire of interpretation, reinterpretation and confusion.

Ultimately, if researchers wish to help teachers to help students, dwelling on teacher beliefs may prove to be a cul de sac on the journey. It might be argued that even if the belief approach is worthwhile, the best outcome achievable would be the identification of a set of flawed beliefs which causes teachers to teach in unproductive ways. Yet even these unhelpful beliefs will not have popped out of thin air, and on a sensible reading of teachers there will be some sort of compelling reasons for them being present in so many teachers. Teachers, and humans generally, would seem to function in more or less sensible ways, adapting to their environments as necessary.

If we are willing to take this step back with Leatham (2006) from merely labelling teachers as inconsistent and instead recognising them as sensible, then we can take a further step back and see that whatever labyrinthine rationales underpin teacher's actions, they are likely to be in response to, and symptomatic of, their adapting to their environment. Taking this second step opens up a methodological opportunity to focus instead on the environment teachers find themselves in.

Environmental factors are far more amenable to rigorous analysis than are teachers' beliefs.

In fact, if it is possible to identify 'best practice', it would be possible to investigate what it is about the environment that has allowed those 'best practitioners' to adapt in the ways that they did to have ultimately formed whatever beliefs they have embraced. Furthermore it would be possible to adjust environmental factors in other settings to see if similar adaptations occur with other teachers. This is a more feasible approach for researching teachers than Rokeach's (1968) hypnotic technique.

Naturally there would be interactions between environmental and personal factors, but if personal factors are the ultimate determining factor of best practice, then all research into best practice is doomed for the simple fact that it is quite untenable to attempt any kind of wholesale personality adjustments of the teaching profession – unless one wishes to advocate certain character traits as being preconditions for employment.

At the end of the day Leatham's (2006) approach has the double advantage of being both logically coherent and theorising about teachers in a way that dignifies them in a way that 'inconsistency theory' does not. Whether teachers are able to respond to the probings of researchers in expected ways or not seems to be unrelated to their status as sensible people. Teachers are no more nor less flawed than other groups of humans and labels of inconsistency do little to further the cause of gaining insight into how teachers do what they do.

In a similar vein, Lerman (2002) essentially advocates a sociological approach to teacher practice as an alternative to the psychological one that dominates the field. He points out the realist nature of the assumption underlying researchers' attitudes toward beliefs in that their methodologies (observations, interviews and questionnaires) are assumed to somehow tap into actual underlying psychological entities – namely beliefs. He points out the inherent circularity of this position in that the methodologies record actions that are presumed to be manifestations of these underlying entities, which are then inferred from the observed actions, that is beliefs are assumed to cause actions, and the observed actions are then used to justify the presence of those beliefs.

The circularity of the belief/behaviour approach within the research literature takes the form of the 'affirming the consequent' logical fallacy:

If B then A

A

Therefore B

Where B represents a teacher's belief and A represents their actions. That is, if a teacher has a certain belief (B) then they will act (A) in certain ways. The teacher is observed to act in those ways (A), therefore they must have the corresponding belief (B). This is identical to reasoning along the following lines: If a person is a billionaire (B), then they could afford to buy an apple (A). A person is observed to buy an apple (A), therefore they must be a billionaire (B).

Of course a related argument could be constructed in the logically valid modus ponens form:

If A then B

A

Therefore B

In this case the argument would run; If a teacher behaves or acts in a certain way (A) then they must have particular beliefs (B). They act in that way (A), therefore they must have those beliefs (B). But this drastically alters the causal relationship inferred by the majority of researchers arguing that actions cause beliefs, not beliefs causing actions. Some, such as Lloyd (2002) and Hart (2002), do make the case for the causal link running in this direction. That is, that changes in pedagogical practice bring about changes in belief, however most want to argue the reverse. The *modus ponens* version of this argument with B representing beliefs and A standing for actions is:

If B then A

B

Therefore A

This runs into difficulties with the observations being of Actions, not Beliefs. What seems to be happening is that the B → A causal arrow is assumed, and that when Actions which do not correspond to the inferred Beliefs are observed, contradictions are deduced to exist. An equivalent situation, in terms of billionaires being able to afford apples, is that when a billionaire is seen at a grocer unable to pay for a bag of apples, the observer concludes that the billionaire is not fully aware of their own financial situation, rather than concluding something else might be going on such as the billionaire having left their wallet at home, or changing their mind and pretending not to have their wallet, or having only foreign currency on hand *etcetera*. The reasoning is that a billionaire should be able to afford apples given their financial status, and if they are not able to afford apples on some occasion then they are behaving in a contradictory fashion. Similarly, teachers should behave in certain ways based on their beliefs, and if they act otherwise then they are inconsistent.

However, the bigger problem remains that if the causal link between beliefs and actions is as strong as seems to be assumed, then there can never be any contradictions. Instead, any observed behaviour that is inconsistent with the beliefs assumed to be driving a teacher's actions must arise from some other set of beliefs, otherwise they would not be acting in the way they were observed.

These difficulties arise because beliefs are not directly observable. Self reporting of beliefs may not be a one to one relationship, and it may be the case that certain beliefs 'cause' teachers to report their beliefs differently to what they actually are. Thus, there are multiple difficulties here.

Taking a more introspective approach and thinking only about myself, I am certain that I have beliefs, and I believe that I have access to those beliefs. However there are discrepancies between what I identify as my beliefs and my actions. If I pick a belief and analyse it, I quickly find that the belief is more a rule of thumb which often collides with other beliefs I have, and that some beliefs take precedence over others in certain situations, not unlike Thagard's (2000) raft analogy. For instance, I believe it is important to be patient with students. Yet there are limits to my patience, and depending on the day I may be very short with students despite my belief. Depending upon my stress levels, mood and so on, I may be quite impatient. Which suggests that some of my beliefs require a greater amount of energy or effort to enact than others, and when that energy is not available those beliefs are jettisoned for less demanding beliefs. These moments of 'weakness' underscore the need for psychic strength to bring my behaviour into congruence with my 'preferred' beliefs. Teachers often describe teaching as a draining occupation, and it might just be this psychic strength is the thing drained by being in a classroom. But it seems clear to me that people can exhibit a wide range of behaviours given the right (or wrong) set of circumstances which is more a measure of their available psychic energy – or libido in the Freudian sense – than the actual beliefs they hold.

This serves to illustrate some of the complexities that relate to interactions between teachers and students. While theories invariably aim to simplify such interactions into more basic structures and patterns, it is inevitable that theories will lose much of the richness and diversity that is present in the reality of individual classrooms. This also opens the door to simplistic interpretations and the discovering of gaps in pedagogical practice where it does not meet the expectations of a given theory – a theme to be revisited in later chapters.

2.2.5 Influences on teachers

The complexity and impact of the classroom environment itself is further bolstered by Sullivan and Leder (1992) who surveyed, observed and interviewed beginning teachers in middle class Australian primary schools as a way of investigating factors influencing these teachers' thinking. Data collection consisted of three main categories: teachers' backgrounds, attitudes, beliefs, understandings and expectations about mathematics teaching; constraints and influences on teachers' pedagogical styles; and teachers' observed and self-reported teaching practices.

Undergraduate teacher trainees were invited to participate in the project. Due to the intrusive nature of the research, and the potentially sensitive stage of participant's development as teachers, volunteers were familiarised with the data collection techniques prior to embarking on the study. This was achieved by having practice teaching sessions observed and video taped, and by completing instruments and surveys capturing teaching beliefs, biographical, attitudinal, and aspirational data.

The study itself spanned both pre- and post-service. Participants took part in structured interviews in their final year of teacher education, three times during their first year of employment, and twice more the following year. Several questions utilised disarming phrasing so that participants' answers were in the context of more familiar or naturalistic settings for example, "You are writing a letter to a friend. What would you say about how the start of the year has been?" (Sullivan & Leder 1992, p.627).

A second part of the interview process involved participants ranking cards containing possible influences on their teaching. Provision was made for them to remove cards they deemed irrelevant or of no significance, and to add (on blank cards) any absent factors they considered important. Participants then ranked these cards, with verbal justification, from most to least influential, and were asked to nominate the hierarchical point below which the influences were felt to be negligible.

Each participant was observed teaching on multiple occasions during their final year of teacher education, and twice more during their first employment year. The observer prepared himself by co-coding a range of live and video taped lessons with an expert colleague, then recoding the same lessons using audio only. Observations used an adapted form of Beeby, Burkhardt, and Fraser's (1979) Systematic Classroom Analysis Notation (SCAN) to track events regarding student centricity of lessons as well as the quality, level and use of concrete tools in teacher explanations. Post-lesson reviews were also conducted on the same day.

Surveys triangulated interview data by collecting a combination of open and structured responses to questions relating to participants; mathematics teaching beliefs and attitudes; views on their teacher education course; and teaching concerns, ambitions and practices. Finally, resulting case studies were member checked and comments collected on their validity. The study initially involved 120 student teachers, but the article in question concentrates mainly on two of seven detailed case studies.

Interestingly, this study found results at odds with the received view. The extant literature reported that the most important influences on novice teachers were; teachers' own schooling experiences, including favourite teachers; transitioning from student to teacher; enculturation into the school, including influences of the principal, colleagues, and parents; resource availability; and familiarity with curriculum content. None of these factors emerged as dominant, or even particularly significant in Sullivan and Leder's (1992) paper. Rather, student responses to teachers were identified as the single biggest influence – to the extent that a misunderstanding by one or two students could result in a class wide intervention by the teachers, and/or the teachers perceiving the lesson as being flawed.

This responding to student responses led teachers to become more teacher centric and directive, to emphasise task completion over concept understanding, and to produce tasks that could be easily completed rather than engaging in open ended or problem solving tasks.

It is noteworthy that none of these student influenced changes were detected by the surveys or interviews, but only emerged from classroom observations. This supported the conclusion that such changes occurred outside of the teachers' awareness.

It is not clear the extent to which teachers' reflection on the success or otherwise of their classes was influenced by the presence of the researcher or other artefacts of the research process. It is plausible that a teacher might lean toward a more critical view of their work in such a context, particularly given the association of the observer with the teachers' recently exited education program. Whilst pedagogical behaviour may have been influenced by a small numbers of students, the extent to which teachers perceived their work negatively may have been exaggerated by virtue of their participation in the study. A similar limitation is acknowledged by the authors in that a participant "may have been influenced by his own evaluations to overemphasize instructions for the tasks and to be more teacher directed" (Sullivan & Leder, 1992, p. 639).

Teacher sensitivity to student reactions may have a number of explanations. The classwide repetition of instructions based on the misunderstanding of one or two students may have resulted from an awareness of those students being indicative of wider misunderstandings, especially if they were stronger students. Alternatively, if those students were amongst the weakest in the class, the teacher may have chosen to avoid drawing attention to their difficulties by speaking to the whole class instead, helping to preserve what confidence they have.

Being sensitive to student reactions to instructions might also stem from more fundamental concerns about being seen as a good teacher. Any deficiency in student understanding might be deemed as reflecting badly on the teacher's ability to teach. Any student not following instructions may be felt to reflect badly on the teacher's ability to control their class. In being set up as authority figures by the community, teachers are expected to issue instructions and to ensure they are followed – it is interesting to note the synonymous nature of the words 'instruction' and 'teaching'. Students not following instructions (either behavioural or educational) may be experienced by the teacher as a challenge to the authority vested in them. This need not manifest itself as student defiance, since anything reflecting badly on the teacher's ability to teach exerts indirect pressure by way of community expectations.

It may be that classroom control could be a considerable limiting factor in what kinds of changes are possible in classrooms of twenty plus students. Such numbers require a strong personality/presence to be able to maintain student behaviour within community proscribed limits, and yet be seen to divest some power to students without invoking situations reminiscent of the Lord of the Flies. The ubiquitous possibility of a classroom revolt, and sensitivity to the first signs of that revolt such as confusion, off task behaviour, or increased noise levels, may explain why teachers are (overly) responsive to student negativity.

The constraints that teachers face in introducing changes to their practice are clearly manifold, and the teachers themselves may not even be fully conscious of them. Arguably such constraints do not come into sharp focus until a teacher is attempting to make a change. In this way the current research project is well placed to explore these constraints more fully since the participant teachers had undertaken to implement changes to their practice, which will plausibly make the teachers much more conscious of the limitations of their circumstances. It also boded well for them being open to the use of a reflective tool to help explore these limitations further.

2.2.6 How to address teacher learning

While my initial approach to teacher learning involved casting teachers in the role of researcher-practitioners, there have been many other suggestions on how best to approach teacher learning. One of these draws upon the educational practices of other professions such as law and architecture where 'case knowledge' is commonplace. Shulman (1986) proposes that a case literature could be used in teacher education via simulations, teaching laboratories and so on, to help inculcate the kind of professional judgements and practices required of good teachers. Shulman (1986) believes such an approach could form the basis of professional teacher examinations – controlled by teachers rather than bureaucrats – and that it could also inform research programs by incorporating both content and process knowledge to amass a body of case literature. Further, given the inherently accessible nature of cases, teachers themselves would be able to make valuable contributions from their own practice, and empowered as research contributors to their own profession.

Such an approach seeks to formalise the kind of stories Connelly and Clandinin (1995) characterise as secret. On their analysis teachers are unlikely to be willing to share anything more than cover stories because of the hostility they perceive to be present in the landscape. And even if teachers did reveal their secret stories they would likely become frozen in time and place, losing the dynamic, spontaneous, and transformative qualities they might once have possessed.

The importance of engaging teachers in reflexive practice is acknowledged by Sullivan and Leder (1992) who propose peer observation as one strategy for improving practice, but also advocating the investigation of whether self-reflective teachers are more or less directive, more or less experienced, and whether reflexive teaching is trait or skill based. It seems reasonable to expect answers to such questions before seeking to recommend reflexiveness, and the increased burden this places on them, as a panacea to teachers.

Feinman-Nemser (2001) claimed that the problems with conventional teacher education and professional development are that teacher training is "weak…compared to teachers' own schooling and on the job experience" and that professional development is usually "sporadic and disconnected" (p.1014). She advocates an overhaul of teacher learning in order to bring about content rich student-centred teaching which encourages and enables teachers to develop their own curriculum, their own knowledge of practice, and to become practical intellectuals.

Feinman-Nemser (2001) surveys a number of "promising" reform programmes and catalogues the qualities she sees as what makes them promising approaches to teacher education. Feinman-Nemser (2001), echoing the views of Connelly and Clandinin (1995), acknowledges the private nature of teaching, and the inherent lack of opportunities teachers have to observe colleagues or discuss pedagogy with them, but then goes on to expound the deleterious effect of these aspects of teaching have on inducting graduate teachers into the profession. In effect new teachers' mentors have little or no experience of mentoring, and the culture of teaching they are being inducted into is one of finding one's own way in isolation.

As far as professional development is concerned, Feinman-Nemser (2001) advocates new approaches which replace external experts with teachers doing the talking and thinking – with a particular emphasis on conversation that involves detailed descriptions of practice, evidence and alternatives. Teachers would form professional communities to share, encourage, critique and support each other and could form partnerships with universities to draw on their resources.

This approach is captured to some extent in Japanese Lesson Study which involves teachers in thinking about their long-term goals for students, developing a shared teaching-learning plan, encountering tasks that are intended for the students, and finally observing a lesson and jointly discussing and reflecting on it (e.g., Lewis, Perry, & Hurd, 2004; Fernandez & Yoshida, 2004). A simplified description of the process, based on Inoue (2010) is as follows:

A group of teachers plans a lesson together

One person teaches while the others watch and write reviews

The lesson plan is revised after the group have discussed how the lesson went

A different teacher teaches, others watch and write reviews

This process cycles through. Of course, a major challenge in this for Australian teachers is having a second teacher observing their teaching since there is a strong culture of privacy associated with classroom teaching. Nevertheless, it is suspected that if this barrier can be overcome, it could result in powerful mathematics teacher learning.

Feinman-Nemser (2001) takes this process further by proposing that teachers design their own curriculum and leverage their professional community affiliations to refine their efforts and increase both their performance and conceptual understanding of pedagogy, producing problem-based, student centred mathematics lessons. The need for such an approach is argued for in Chapter 7 as an antidote to other social pressure groups.

It is also worth noting that the TTML project appeared to deliver on many of these suggestions, making it an ideal context within which to explore the factors influencing teacher learning. It is also within this spirit that the RTFS was envisaged to be of use in empowering teachers to become practitioner-researchers by facilitating their own classroom based research and analysis.

2.3 ***Methodology & Methods***

This section provides information on the original methods and explores relevant methodological literature. It also provides some details on the setting of the thesis and an overview of the technological tool developed as part of the research.

2.3.1 Overview

The initial research questions for this study fell into two main categories;

- The willingness or otherwise of teachers embracing new tools – including the constraints teachers perceive, and the conditions required for them to make the necessary changes.
- The kinds of impact the new tool has on teachers who use it.

The nature of these questions made them amenable to several methodological approaches: it would be possible to conduct surveys of a large number of teachers; or case studies of a small number of teachers. Given this project was run in parallel with the larger TTML study it would be possible to gain access to 30-40 teachers, therefore it was decided to draw on the strengths of both of these options by conducting semi-structured interviews/case studies with a small number (2-5) of teachers, and using surveys to collect more general information from the remainder of the cohort.

This section canvasses some of the issues associated with social and educational research and provides details of the methods employed as part of this thesis.

2.3.2 Methodology

The call for social scientists to emulate the physical sciences dates back to at least the mid-nineteenth century, and a century and a half later a strong view still persists within society that mathematical models are the only valid form of knowledge (Guba & Lincoln, 2004). However, a century of the philosophy of science has identified many problems with the 'scientific method' as well as identifying many problems that exist with the notion of knowledge itself, including whether it is actually possible to know anything at all (e.g., Gettier, 1963).

In recent decades a number of problems have been identified with relying solely on quantitative methods and there has been a reaction against them within social and educational research. For instance, whilst it is possible to derive generalisations from statistically analysing large cohorts of participants, it is not necessarily possible to reverse the process and apply these conclusions meaningfully to individual cases. An extension of this criticism claims that whilst inanimate objects might be treated as simplified mathematical entities and stripped of extraneous detail, the same cannot be said of humans – human actions can not be truly understood by excluding meaning, motive and purpose from the analysis (Guber & Lincoln, 2004).

This is not to say that quantitative data cannot be of use when investigating human contexts, but there are compelling reasons to utilise qualitative methods as well. Arguably it would be possible to utilise the advantages of both qualitative and quantitative techniques in a mixed methods approach which, if combined carefully, could provide richer triangulation opportunities than would be otherwise possible by employing a single methodological approach.

This thesis utilised survey techniques which were analysed with conventional forms of quantitative analysis. Additionally, qualitative data were collected through semi-structured interviews, observations and document collection. Qualitative data were also collected from a subset of participants in the form of email exchanges.

2.3.2.1 Data Collection Issues

As with most journeys, it seems advisable to be as prepared as possible when undertaking research. The more thought that goes into the types of data to be collected, and why, the better. Whilst it is not possible to anticipate every difficulty that might arise from certain data collection decisions, it is possible to consider the kinds of problems that can result from poor choices. Erickson (1986) nominated five major inadequacies that can arise from poorly designed data collection. These are:

- Inadequacies in the amounts of evidence collected;
- Insufficient variety in the types of evidence sought;
- A lack of falsifying or disconfirming evidence – or a failure to attempt to collect these;
- A failure to analyse disconfirmatory evidence, and;
- The faulty interpretations of evidence or a lack of awareness that evidence may not be an accurate reflection of the setting under investigation. (p.140)

The initial study was designed to address as many of these potential problems as possible. The issue of quantities of evidence was tackled by ensuring that sufficient participants were recruited to allow for the use of parametric techniques as part of survey analysis. The intention was to conduct t-tests comparing sub-group responses. Given that cohort size requirements are more stringent for parametric than for non-parametric tests, and that larger sample sizes would not preclude non-parametric tests from being performed as well, it was deemed suitable to recruit a larger number of participants. As t-tests approximate z-tests when $n \geq 27$, the intention was to recruit a minimum of 30 teachers to achieve the necessary higher degrees of freedom, thus alleviating the risks associated with assuming equivalence of variance and the normality of underlying populations (Bhattacharyya & Johnson, 1977). Such levels of recruitment were also beneficial from a qualitative data analysis perspective since higher numbers of participants greatly increased the possibility of not only capturing a diversity of views, but also increased the chances of these views recurring within the sample. Any repetition of patterns and themes was potential evidence of the existence of distinct groups within the cohort of participants which would be important to identify as part of the analysis phase.

Erickson's (1986) second point concerning the variety of kinds of data to be collected was addressed by adopting a mixed methods approach. This point essentially relates to the triangulation of data, being able to draw conclusions based on two or more sources of information. In this study survey data were related to aspects of the semi-structured interviews, and empirical data were to be used as prompts for discussion as well as for defining categories within the participant cohort. Where relevant, documents were collected as evidence of particular approaches to compare with the approaches observed by the author and reported by the participants.

The third and fourth points Erickson (1986) make relate to experimental and quasi-experimental research following Popper's (1963) claim that scientific enquiry must be based on attempts to falsify theories. There have been many critiques of Popper's (1963) claims about the demarcation between science and pseudo-science (e.g., Kuhn (1962) and Feyerabend (1975)) but for the purposes of this research it is sufficient to take Erickson's (1986) points as valid ones. The lack of falsification can not be taken as proof that a theory is true, only that it has not been falsified. Or to paraphrase Popper (1963), no theory can be proven to be true, only false. Erickson's (1986) points about disconfirmatory evidence were operationalised by ensuring that instances of contradictory data were given due consideration when analysing results. Arguably my research ultimately took a different direction as a result of collecting evidence that in some ways could be considered disconfirmatory.

Erickson's (1986) last point concerning faulty interpretations and inaccurate data pertain to when the researcher "fails to have understood the key aspects of the complexity of action or of meaning perspectives held by actors in the setting" (p.140). To some extent this problem is impossible to eliminate entirely since, arguably, not even the actors fully understand the complexity of their own actions or perspectives. However, the point is more akin to Pike's (1967) emic/etic distinction in that the account or theory rendered by an outside researcher (etic view) will be quite different to the insiders' (emic) view.

Glaser and Strauss (1967) attempt to mitigate this distinction by recommending a process of 'grounded theory', or developing theories that would be readily recognisable by the inhabitants of the setting. Their approach is semi-inductive whereby theory is generated from data by a process of constant comparison of the abstracted theory to the data available. In a move almost diametrically opposed to Popper (1963), Glaser and Strauss (1967) prohibit pre-conceived hypotheses and make a virtue of a process Popper (1963) labelled as ad hoc theorising or as a "conventionalist twist" (p.48) whereby a theory is modified to accommodate falsifying data. For Popper (1963) this was a hallmark of pseudo-science since it flies in the face of a theory being falsifiable. It may be a measure of the extent to which qualitative methods have gained credibility, despite this clash with Popper's (1963) views, that Glaser and Strauss' (1967) grounded theory has accrued nearly 10,000 citations according to Google Scholar (9,872 as of 26 February 2010).

Whilst not attempting to fully emulate the grounded theory approach in this study, there was a clear intention to allow themes and patterns emerge from the data. The emic/etic distinction was somewhat reduced by my own proximity to the teaching profession. However, even within teaching there are cultural gaps that cannot be bridged comprehensively. For instance, many participants were Catholic Primary School teachers, while my experience is predominantly in Government Secondary Schools. Because of this it was deemed important to take further steps to minimise these gaps, and so identified themes were member checked with participants to ensure these themes maintained authenticity.

2.3.3 Location

The Task Types and Mathematical Learning (TTML) project recruited teachers from three clusters of Victorian schools. The clusters were located in Berwick (a burgeoning outer suburb in a growth corridor 45 km South East of Melbourne), Malvern (a well established inner suburb 5 km East of Melbourne), and Geelong (a regional centre 80 km South West of Melbourne). The project was designed to run over the course of three years, incorporating regular professional development meetings for participants.

Participating schools belonged to either the State or Catholic sectors, with considerable levels of support for the project being shown from within the Victorian Government Department of Education and Early Childhood Development (DEECD) and the Melbourne Catholic Education Office (CEO). The TTML project targeted the middle years of schooling (Years 5 to 8). Fifteen of the participating schools were primary schools and three were secondary colleges.

2.3.4 Participants

All TTML participant teachers were invited to take part in this study, which consisted of approximately 15 teachers from each of the three clusters of schools. Typically each school had two or three teachers involved in the TTML project, with levels of experience ranging from first year out through to several decades of teaching practice. The pool of potential teachers was predominantly female with 30% of participants being male.

2.3.5 Methods

2.3.5.1 Overview

Overall, data collection for the initial research questions consisted of three distinct sections. First, teachers were asked to complete a short questionnaire to collect basic biographical data and some Likert scale responses to several questions, including obtaining names or samples of their preferred mathematics teaching resources. Second, teachers were asked to nominate two questions they would like feedback on from students; one being something they believe they deal with well, the second they felt was an area they struggled with. These questions, along with two other standard questions, were loaded into the Real Time Feedback System (RTFS) and responses collected from their students every few minutes during a mathematics session. The third and last stage consisted of discussing the results of the RTFS data after the mathematics session and exploring any implications the teachers saw for their own pedagogical practice.

2.3.5.2 Stage One – Short teacher questionnaire

The preliminary questionnaire was designed to collect sufficient data to be able to provide categories for subsequent comparative analysis. The categories to be compared were sex, number of years of experience, school sector, year levels taught, reported confidence with teaching mathematics, participation in TTML meetings, reported sense of collegiate support, reported sense of security within the school, reported satisfaction with access to mathematical teaching resources, and reported belief in the importance of making mathematics relevant to students' lives. The full questionnaire is included in Appendix I.

2.3.5.3 Stage Two – Teacher feedback questions

It was hoped that having teachers reflect on their practice and being able to test their assumptions would be of interest and benefit to the participating teachers. Teachers often have a strong sense of what they do well and where they struggle, so this approach would provide them with an opportunity to obtain student feedback directly and quickly.

To these ends teachers were asked to think about and nominate two areas they would like feedback on from their students – one which they felt catered to a strength of their teaching (e.g., I relate well to the students), the other which addressed an area they felt less confident with (e.g., I struggle to explain fractions clearly). These areas of interest were expressed as two questions that teachers could have their students answer every five minutes throughout a lesson. For example the two areas suggested above might become;

1. How well do you think Ms Teacher understands your learning needs right now?

2. How well do you now understand what Ms Teacher has been explaining?

The number of questions posed was not restricted by any technical consideration per se, but rather by the desire to minimise the disruption to the flow of the lesson by maximising the speed with which students could provide their responses. It was also possible to vary the response rate from every five minutes to any other interval, or to have the responses triggered by the teacher directing the class to submit their data, or having students control their own response rates. These options were discussed with teachers as possible variations after the initial set of data was collected, including the possibility of having students nominate questions for the class to provide feedback on.

Once the teacher questions were formulated, they were loaded into the Real Time Feedback System (RTFS). This consists of a web page hosted on a laptop computer which could be used to serve the page to a set of 25 iPod Touch devices via an 802.11g Wireless (WiFi) router located in the classroom (see Figure 2.1).

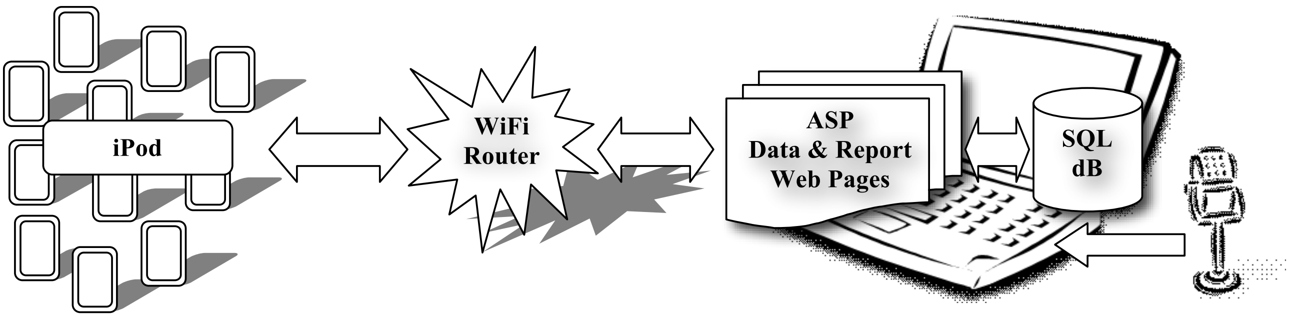


Figure 2.1 Diagram of the relationships between hardware and software components of the RTFS.

Although any portable browsing device would be suitable, the iPod Touch has a unique navigation interface whereby the entire surface is a touch sensitive screen that can be zoomed in or out as desired by either tapping the screen, pinching thumb and forefinger together, or spreading thumb and forefinger apart. Each iPod was configured to browse the locally hosted web page so that each student could be given an iPod to use and to respond by tapping on a visual Likert scale as prompted. The data submitted by students was then processed by a web application utilising Active Server Pages (ASP) (essentially a web based application) and stored in a relational database also hosted on the laptop. Various triggers and stored procedures within the database enabled an administrative web page to produce web based reports that could present the student feedback in graphical formats. Audio of the lesson was also recorded onto the laptop (using Audacity software and the laptop built in microphone) to provide a timeline for subsequent analysis.

Given the novelty of the iPod devices in 2007, it was important to ensure that students were given an opportunity to familiarise themselves with the navigation system and to have a chance to explore the device generally prior to formal data collection. The iPods ordinarily have a number of other features and functions that were effectively disabled for the purposes of the project, restricting them to web browsing and a minimum number of other capabilities.

A set of other ASP web pages were incorporated into the system as a means of inducting students into the use of the iPod navigation interface. These pages had simple instructions that gave immediate feedback when students succeeded or failed to tap the correct section of the screen. It was possible to track student progress on these induction tasks and offer additional assistance as required until all students mastered the requisite navigation skills, however it was found that students progressed through these basic navigation pages with relative ease and were quickly able to master the skills required to use the iPod to interact with the RTFS.

It was not always possible to conduct the reflection, induction, data collection, and analysis in a single day, so it was sometimes necessary to spread the steps across two consecutive days, however in most instances the mathematics session was selected because it immediately preceded recess, lunch, or the end of the day making it possible to go through the results with teachers immediately.

During the feedback sessions students were provided with iPods at the start of the mathematics session and given the opportunity to refamiliarise themselves with the browser interface having gone through the navigation induction previously. They were assured that all of the data they submit was completely anonymous, and that the iPod would flash every five minutes to remind them to submit another set of answers.

Two additional standard questions were included in the RTFS to collect data on how interesting the students were finding the lesson, and how hard they felt they were trying. It should be noted that the emoticons used as Likert prompts are animated gif images that can be tapped rather than static images (see Figure 2.2).

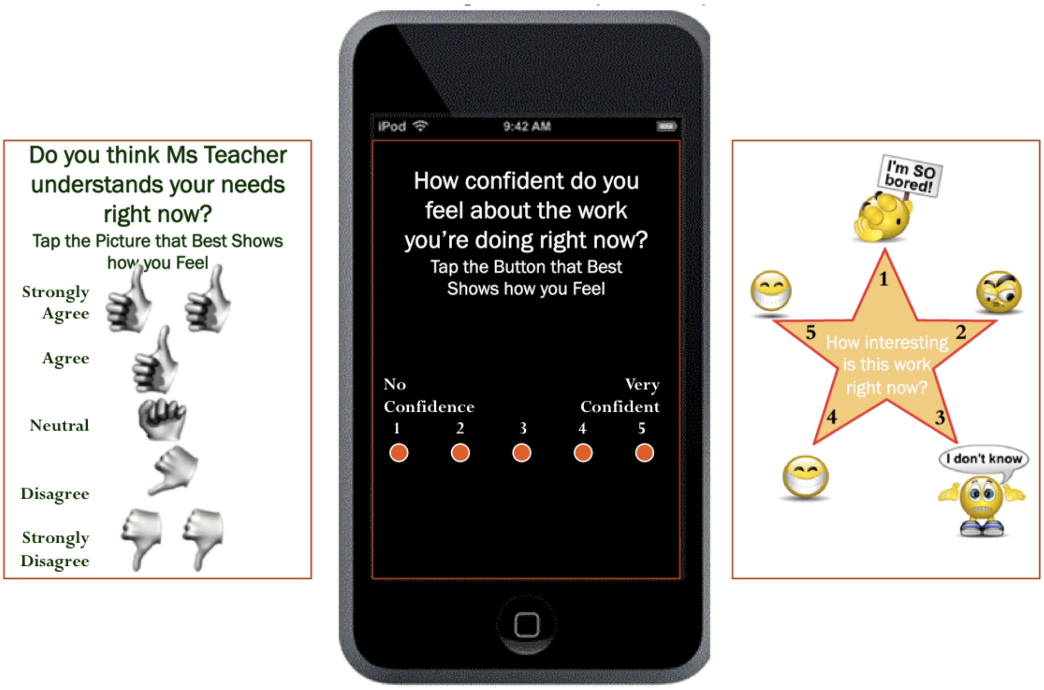


Figure 2.2 Samples of feedback screens from RTFS.

Others have used technological prompts previously, as reported in Moore, Prebble, Robertson, Waetford, and Anderson (2001) wherein individual students were given tape recorders which played tones every few minutes during a lesson. These audio prompts signalled for students to make entries on an accompanying paper and pencil instrument. The chief difference between such approaches and the RTFS is that the data are also collected, collated, and processed by the same technology which delivers the prompt.

2.3.5.4 Stage 3 - Analysing and Discussing the RTFS Results

Upon successfully collecting student feedback it was possible to spend some time going through the data collected with the teacher. The overall aim of this analysis was to have data on hand that the teachers have collaborated in collecting, the relevance of which would be self evident, and provide a grounding in reality for the ensuing discussions. Initial analysis and discussion centred on the graphs of student responses to the four questions (see Figure 2.3), mapped against what was happening in the class at the time – as ascertained from the audio recording.

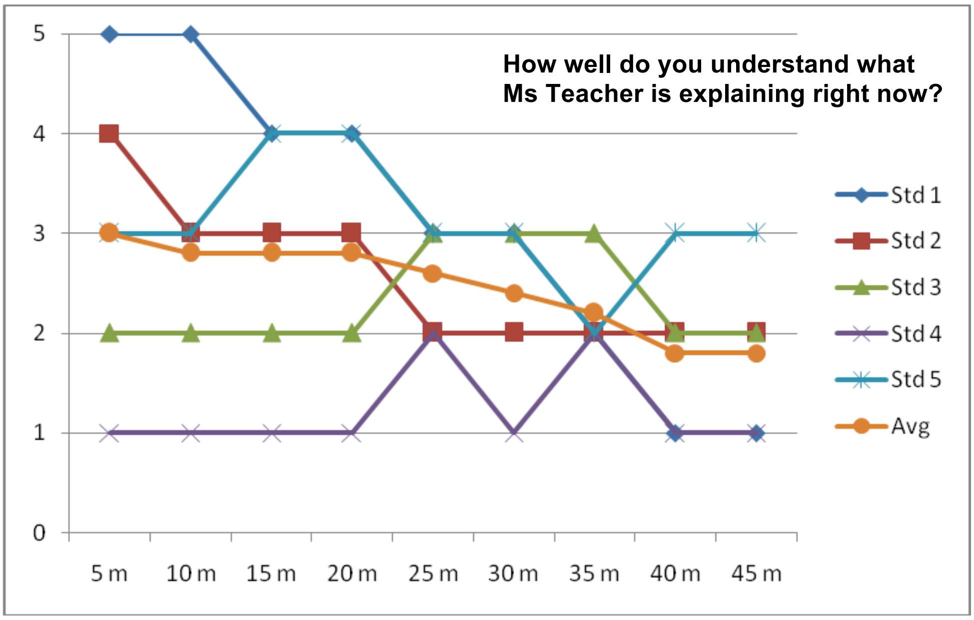


Figure 2.3 Simplified sample report from the RTFS.

The advantages of having an interview schedule to help structure discussions with teachers had the double advantage of ensuring consistent data collection across all participants, while leaving the interview flexible enough to allow conversations to pursue additional topics as they arose.

It was possible to view the response graphs on the laptop at any stage of the data collection cycle, so it was also possible for a teacher to monitor student feedback during the lesson itself and modify their teaching as they saw fit, however this did not actually happen in practice, and the intention was to reserve analysis until after the lesson hasd been completed. It would also be possible to display the results to the entire class by using a data projector if this was thought to be of value, or if the question/feedback stimulus warranted it, but this aspect of the RTFS was not utilised either in this study.

Teachers were also given the opportunity to borrow the equipment for further data collection if they found it to be of interest and/or use to them, and one measure of the usefulness of the RTFS approach was the extent to which teachers were interested in taking up this offer to use the RTFS as is, and in their willingness to explore other possible configurations such as using live data monitoring, data projectors, or student generated questions.

The central questions to be explored with teachers were:

1. What sense can you make of these results, what do you think we can conclude about your questions?
2. Is there anything here which you find surprising or confusing?
3. How do these responses strike you? Are there any patterns you think are meaningful?
4. Is there anything that you would do differently in light of these results? What obstacles do you think you would have to overcome in making these changes?
5. How useful/helpful do you think this kind of process is in terms of yours or others' professional learning?
6. Could it be made more useful? How? Would live data feedback be of any use to you? Could you imagine using it with a data projector displaying a feedback 'worm' to your class? What sort of situations might that be useful?
7. Would you recommend this to a colleague or would you be interested in borrowing the equipment to run more of your own feedback sessions?

It was anticipated that this process would be repeated with some participants as required/requested, and as part of the software development cycle where suggested improvements would be implemented and tested with the relevant teachers.

2.3.6 Ethical Considerations

Ethical approval for this project was obtained in conjunction with the application submitted by the TTML project to the Monash University Human Research Ethics Committee. All participants were assured of the confidentiality of their responses, their ownership of all of their data, and their right to terminate their involvement at any stage.

Even though the teachers had already agreed to take part in the TTML project it was important to assure them that participation in this study was completely voluntary. It was important to be aware of the time commitment these teachers had already made to TTML and to ensure that there was no pressure placed upon them to comply with potentially unreasonable scheduling.

Teachers may have felt threatened when discussing the AIM test data, and may have experienced pressure during the live data collection (stage six) and subsequent discussion of the results. It was therefore important to be sensitive at all times to their moods and feelings during data collection and to give the option of taking a break or postponing completion of any or all stages.

It was also important to ensure that both teachers and students were aware that the RTFS only collected anonymous data, so that the student data collected by the teacher during stage six could not be used to identify responses from individuals. In keeping with the mental health risk mitigation of the TTML project, teachers were reminded of their entitlement to professional counselling and relevant contact details provided as part of obtaining their agreement to participate.

2.3.7 Limitations

There are a number of limitations with this study. The first is its heavy dependence on the reports and perceptions of the teachers involved. Whilst there is some triangulation of these reports with externally verifiable data (attendance at TTML meetings, samples of authored tasks, resources used in teaching, colleague responses) there is nevertheless a heavy reliance on the honesty and generosity of the participants.

A second limitation is the size of the cohort. Although 40+ participants are enough for some statistical analysis, splitting this group into smaller categories then become problematic in statistical terms, undermining the strength and generalisability of any conclusions drawn on this basis.

Another limitation may arise from disruption to the class due to the nature of the research. It is anticipated that there may be problems with students being overly distracted by the instruments, and as a result the instruments themselves subverting the measurements they are intended to make – a macroscopic parallel to the Heisenberg uncertainty principle.

Although some disruption to classes was inevitable, it proved to be that students tended to be less excited by the technology than adults typically expected. The rate of technological uptake by students is so high that it is quite possible that many students had their own iPod Touches or equivalents (Nielsen, 2005). Also by restricting the iPod functionality to web browsing only, and restricting the browsable sites to only those part of the RTFS website, minimised this concern.

Interestingly, Moore et al. (2005) found their technique significantly improved the on-task levels and work quality of their subjects, suggesting that the RTFS approach might be adapted to bring about similar improvements in students attending to the mathematics lesson.

In any case, the key purpose of this use of instruments is to provide a vehicle for teacher reflection, so the issue of data accuracy and class disruption is of a second order. Sustained use of the RTFS would rapidly diminish the novelty factor, desensitising students to the recording process, and teachers could have more confidence in the data they collect. The original aim of this project was to establish whether using technology in this way held any promise as an aid to pedagogical reflection.

2.4 *Conclusions*

The original destination, outlined in this chapter and O'Donovan (2008), was to explore a way to help foster teacher learning whilst working within the constraints imposed by the secretive nature of teaching (Connelly & Clandenin, 1995), and the role that teacher reflection could play in forming the basis for professional communities (Feinman-Nemser, 2001). The intention was to develop a technological tool that would enable mathematics teachers to readily capture data from their students during class and allow them to thereby be able to analyse responses to research questions of their own derivation. The thinking was that any approach that enhanced teachers' capacity to reflect on their own practice, based upon empirical data of direct interest to themselves and under their own control, would be worthwhile.

To these ends an electronic feedback system was developed, the Real Time Feedback System (RTFS). This consisted of a laptop computer acting as a database web server. The laptop hosted an interface for teachers to enter details about their class (student name, gender, age group, ability group etc.), and to configure a set of pedagogical questions that they would like to collect responses to throughout any given lesson (e.g., How hard are you trying at the moment?). Students were each given a handheld computing device, an iPod Touch, which could be used to browse the web pages generated by the laptop over an ad hoc local area network via WiFi connectivity. Students would be prompted to respond to the set of questions after a set period of time, say every 10 minutes or so. Depending on the teacher, students could use other features of the iPod Touch (e.g., the calculator) during the intervals between responses. The laptop also recorded the audio of the lesson as a way of being able to retrospectively identify what was happening in the class during any particular response period.

At the end of the lesson, or any time convenient, the teacher could review the feedback on the laptop in one of several graphical formats. Depending on the information originally configured teachers could view data from individual students, the entire class, or subsets thereof (e.g., responses by ability group). The digital audio recording was also available should the teacher wish to jog their memory as to what was happening at a time of interest.

The next chapter deals with some aspects of the development of the RTFS and some of the results that were obtained from using the system in classrooms which marked the divergence of this project from its original intentions.

CHAPTER 3

Developing and using the RTFS

> "There are two distinct classes of what are called thoughts: those that we produce in ourselves by reflection and the act of thinking, and those that bolt into the mind of their own accord"
>
> (*Thomas Paine)*

3.1 *Development of the RTFS*

While this section deals with results garnered from the Real Time Feedback System (RTFS) it does so in a concise manner due to the change in focus that ultimately occurred with this project. Had the original approach prevailed then a far greater emphasis would have been placed on providing details around the hardware, software development, technical difficulties that had to be overcome, case studies and their analyses. However, in light of the direction this thesis has taken, it is sufficient for the purposes of the overall argument to present here a restricted account of these aspects of the research, starting with the development of the RTFS.

3.1.1 Description of the RTFS

The RTFS was a mixture of portable computing connecting wirelessly (over WiFi) with a custom built web based application. Any device with a web browser could access the software, and the iPod Touch was deemed the most appropriate because of its unique, user friendly, navigation system and inbuilt WiFi capability.

The software generated input screens for teachers to load class details, prepare feedback questions for students, and to review the responses graphically. The RTFS also generated input screens for students so that they could provide feedback based on their teacher's questions. In the background, the RTFS wrote the various inputs into a relational database, and retrieved relevant data as necessary.

The RTFS software, database and web servers, were hosted on a single laptop running Windows Server 2003, which also provided the networking service to the iPod Touches via a WiFi router, and also ran an audio recorder during the classes.

3.1.2 RTFS Networking

The network was an ad hoc Wireless Local Area Network (WLAN). The WiFi router was connected via Ethernet cable to the laptop which acted as the primary Domain Controller. Network addresses were initially allocated dynamically to devices as they negotiated a connection with the laptop using the Dynamic Host Configuration Protocol (DHCP). The generic Internet Protocol (IP) address range of 10.0.0.1 to 10.0.0.30 was used to avoid any conflict with existing school networks which typically operated in the 192.168.0.0 to 192.168.255.255 range of addresses. In the event of any clash between the WLAN IP addresses and existing networks, it was possible to simply reconfigure DHCP address range being offered by the laptop. The IP address was used within the database to link sets of feedback records together. This eliminated the need for students to login to the system to generate a unique identifier since their device would have a unique IP address for identification purposes.

However, it soon became evident that teachers wanted to identify individual student feedback in the RTFS generated graphs. Since the DHCP setup meant that each device obtained an IP address upon connecting to the WLAN, there was no guarantee that the same device would obtain the same IP address across different sessions, and there was no logical connection between the physical number engraved on the back of each iPod Touch and its IP address. To overcome this, each iPod was preconfigured with a static IP address instead. Thus iPod number 7 was given 10.0.0.7, iPod number 23 was given 10.0.0.23 and so on. This ran the risk of having to readdress each device in the event of a conflict, but fortunately this was never an issue at any of the schools where data were collected.

3.1.3 RTFS Web Server

The web server used was the Internet Information Service 6.0 (IIS) that was a standard component of Windows Server 2003 operating system. This was one of the reasons for installing Windows Server 2003 on the laptop, because IIS is a robust native Windows service and supports Active Server Page (ASP) applications. This would allow me to develop a web based application using Microsoft's ASP platform which would enable data to be written to, and retrieved from, a relational database. The interface between IIS and the database utilized Open Database Connectivity (ODBC) functionality which was also implemented in Windows Server 2003. The basic setup screens are shown below in Figure 3.1, and it can be seen here that the database connection reference within the ASP applications was RTFS_ODBC to avoid any possible confusion. The connection method was configured as Named Pipes over TCP/IP as a result of performance tests that showed a 20% faster read/write response for this application.

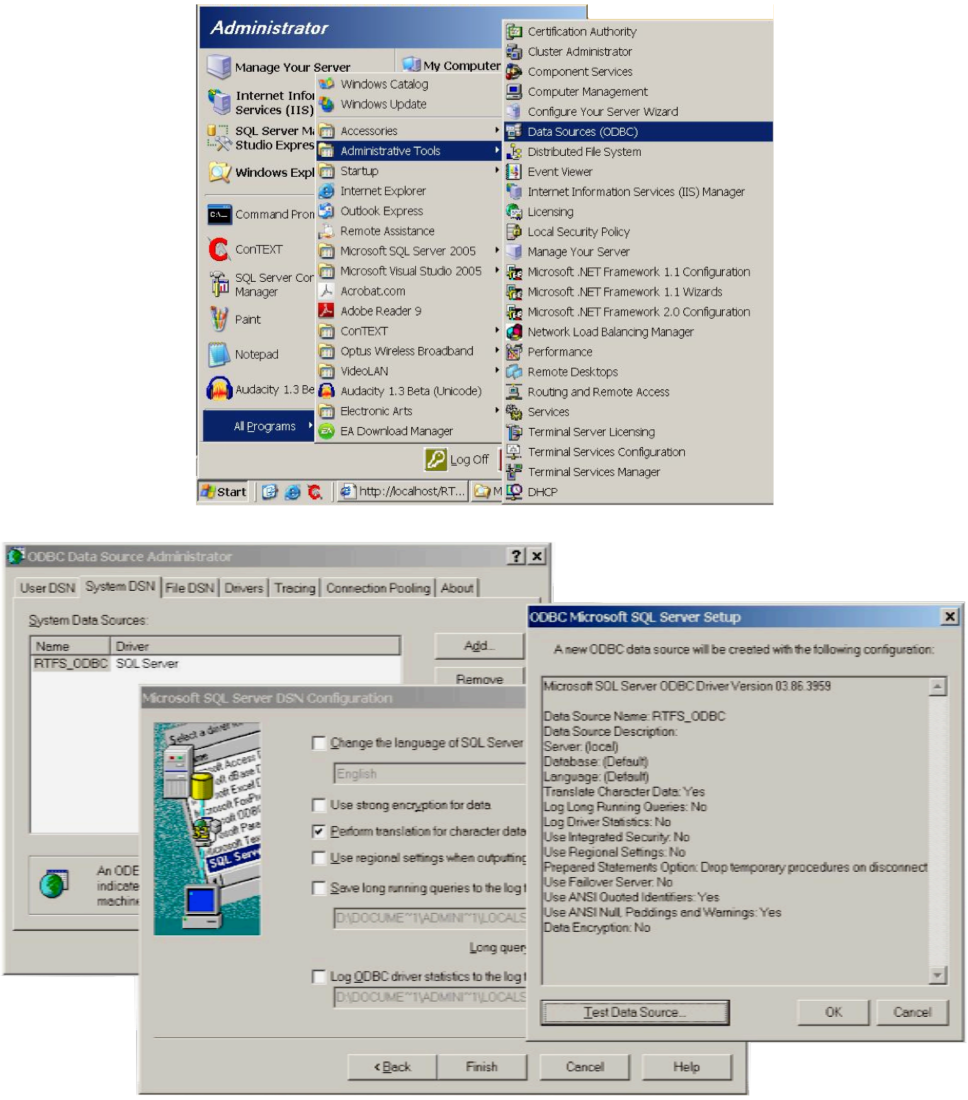


Figure 3.1. Data source interface for the RTFS connection in Windows Server 2003.

3.1.4 RTFS Database

The other main reason for selecting Windows Server 2003 was that it provided seamless integration with an industry standard relational database that utilized Microsoft SQL Server 2005. Like nearly all other commercial databases, Microsoft SQL Server 2005 uses Structured Query Language (SQL) for accessing data, and supports stored procedures, triggers, and views. Whilst the RTFS database was relatively simple, it is common in the development of applications for database queries to first be written into the application itself, in this case ASP pages, and gradually migrated to database stored procedures, functions, or triggers as development progresses and certain processes become more central or universal, and efficiency becomes more important. Since the RTFS is essentially a prototype application there were only a small number of stored procedures and functions written initially. Further development would have seen this number grow, along with a number of triggers and views that would have simplified subsequent maintenance and refinements.

The database diagram below (Figure 3.2) shows the main tables and the relationships between them. The structure is not yet fully normalized since some data redundancies exist, and not all primary and foreign key relationships were strictly enforced, since non-normal databases are conducive to a more rapid, ad hoc, development process which can be decomposed into the relevant sub-tables and relationships once the central design has been stabilized and the key data columns identified.

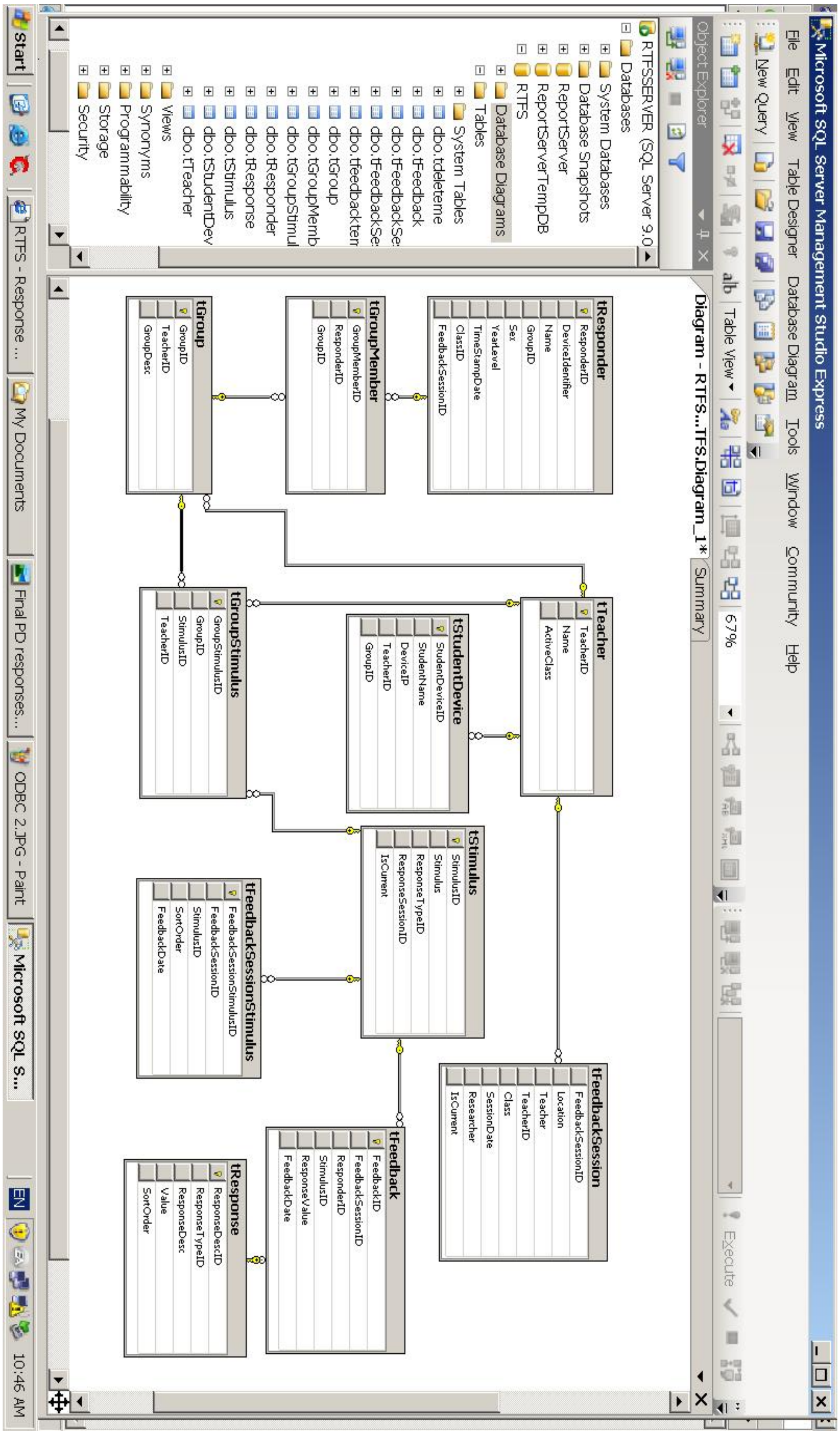
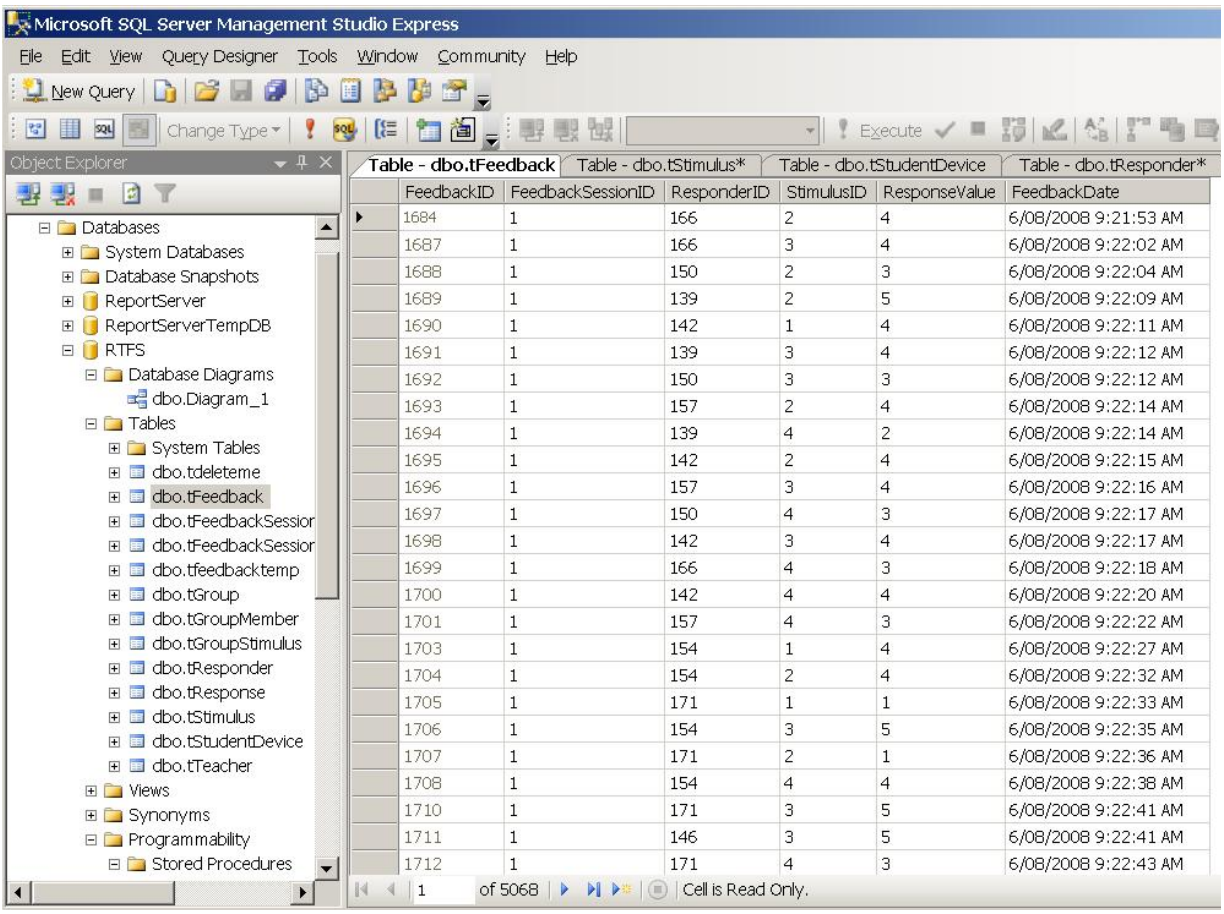


Figure 3.2. Database diagram for the RTFS database.

Data were stored in the database in three distinctive categories; User, Stimulus, and Response. The user tables consisted of data that identified the teachers, their students, and any relevant groupings of the students. The stimulus data related to the questions that were to be asked, the kind of responses desired for these questions, and any tailoring of questions to specified groups of students. The response data dealt with the actual data collected and individual session identification data.

To illustrate some of the data hierarchies a sample of actual feedback data from the table tFeedback is shown below in Figure 3.3 below.



FeedbackID	FeedbackSessionID	ResponderID	StimulusID	ResponseValue	FeedbackDate
1684	1	166	2	4	6/08/2008 9:21:53 AM
1687	1	166	3	4	6/08/2008 9:22:02 AM
1688	1	150	2	3	6/08/2008 9:22:04 AM
1689	1	139	2	5	6/08/2008 9:22:09 AM
1690	1	142	1	4	6/08/2008 9:22:11 AM
1691	1	139	3	4	6/08/2008 9:22:12 AM
1692	1	150	3	3	6/08/2008 9:22:12 AM
1693	1	157	2	4	6/08/2008 9:22:14 AM
1694	1	139	4	2	6/08/2008 9:22:14 AM
1695	1	142	2	4	6/08/2008 9:22:15 AM
1696	1	157	3	4	6/08/2008 9:22:16 AM
1697	1	150	4	3	6/08/2008 9:22:17 AM
1698	1	142	3	4	6/08/2008 9:22:17 AM
1699	1	166	4	3	6/08/2008 9:22:18 AM
1700	1	142	4	4	6/08/2008 9:22:20 AM
1701	1	157	4	3	6/08/2008 9:22:22 AM
1703	1	154	1	4	6/08/2008 9:22:27 AM
1704	1	154	2	4	6/08/2008 9:22:32 AM
1705	1	171	1	1	6/08/2008 9:22:33 AM
1706	1	154	3	5	6/08/2008 9:22:35 AM
1707	1	171	2	1	6/08/2008 9:22:36 AM
1708	1	154	4	4	6/08/2008 9:22:38 AM
1710	1	171	3	5	6/08/2008 9:22:41 AM
1711	1	146	3	5	6/08/2008 9:22:41 AM
1712	1	171	4	3	6/08/2008 9:22:43 AM

Figure 3.3. Sample data from table tFeedback.

Each row has a unique identifier, the Primary Key FeedbackID. The rest of the record represents the feedback to a single question by a student, consisting of the code allocated to the particular lesson for that class (FeedbackSessionID), the code associated with the device used by a particular student (ResponderID), the question being answered (StimulusID), the answer provided (ResponseValue), and the time of the response (FeedbackDate). For instance, the rows with a FeedbackID of 1703, 1704, 1706, and 1708 contain the feedback from the student with a ResponderID of 154 to questions with StimulusID's of 1, 2, 3, and 4 respectively. The student chose Likert value 4 for question one, then five seconds later selected 4 for question two, followed by option 5 three seconds after that, and option 4 another three seconds after that. While this student was considering their answers for the third and fourth questions, another student (ResponderID = 171) provided their own answers to questions one and two.

Three of the components of each row, or record, in this table are explored a little further to clarify how they relate to several of the other tables in the database. These will be the ResponderID, StimulusID, and ResponseValue.

3.1.4.1 ResponderID

The ResponderID refers to the unique identifier of the tResponder table, for which sample data is provided in Figure 3.4 below. Each row in this table provides information relevant to one student, namely the IP address of their iPod Touch (Device Identifier) which, it will be noticed, falls within the range of 10.0.0.101 to 10.0.0.126, with the last two digits corresponding to the number engraved on the back of the actual device. The student's name is recorded in the Name column, a code corresponding to a group that the teacher identifies this student with appears in the GroupID column, the students' sex in the Sex column, and the year level in the YearLevel column. Further data dependencies exist between the GroupID column and three other tables tGroup, tGroupMember, and tGroupStimulus which are used to determine which questions to ask of students who have been assigned to a particular group, however the details of these relationships will not be looked at further.

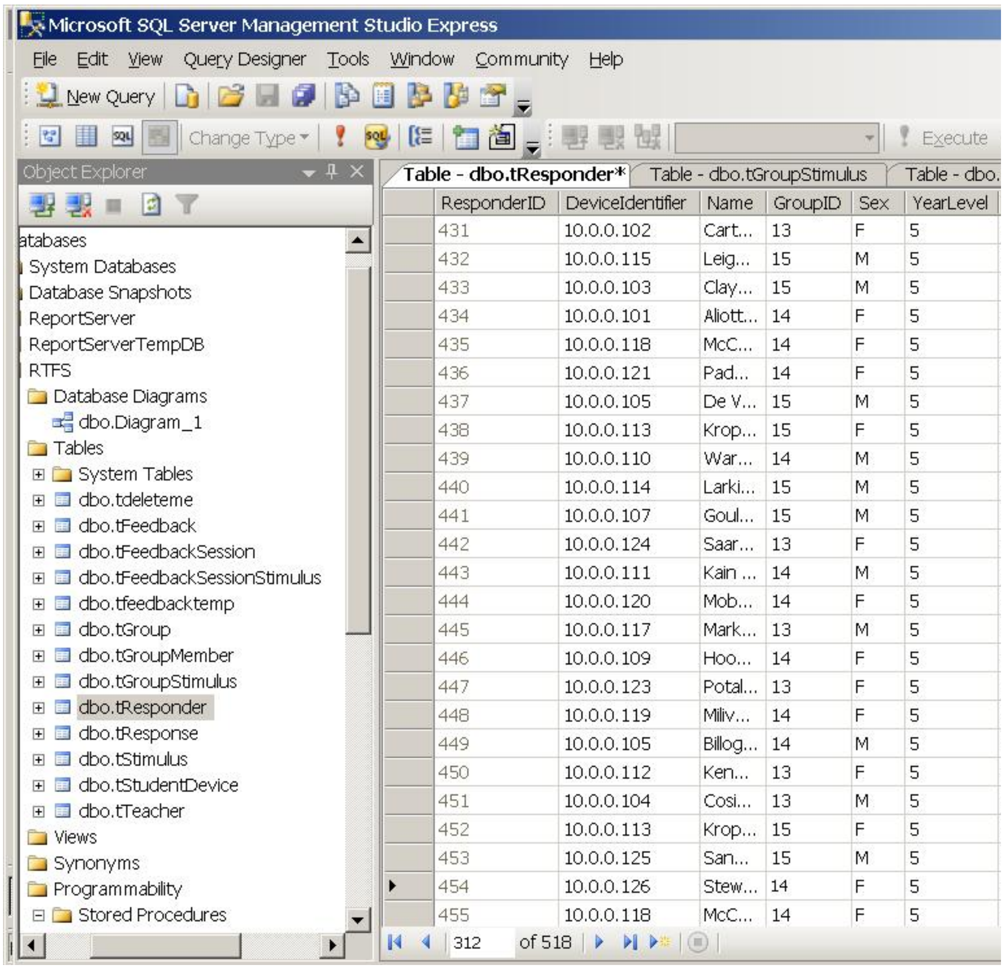


Figure 3.4. Sample data from table tResponder.

3.1.4.2 StimulusID

The StimulusID in tFeedback corresponds to the unique identifier in table tStimulus, of which a sample of data is shown in Figure 3.5. The Stimulus column of this table contains the text of the questions which are posed to students. The ResponseTypeID column relates to the unique identifier of the tResponseType table which contains the response options available to students for this particular question. The IsCurrent column is a flag used to determine whether a question should be displayed in a list of questions for teachers to choose from. This allows questions that have been found to be unsuitable in some way to be culled from the list of available questions without actually deleting them from the database.

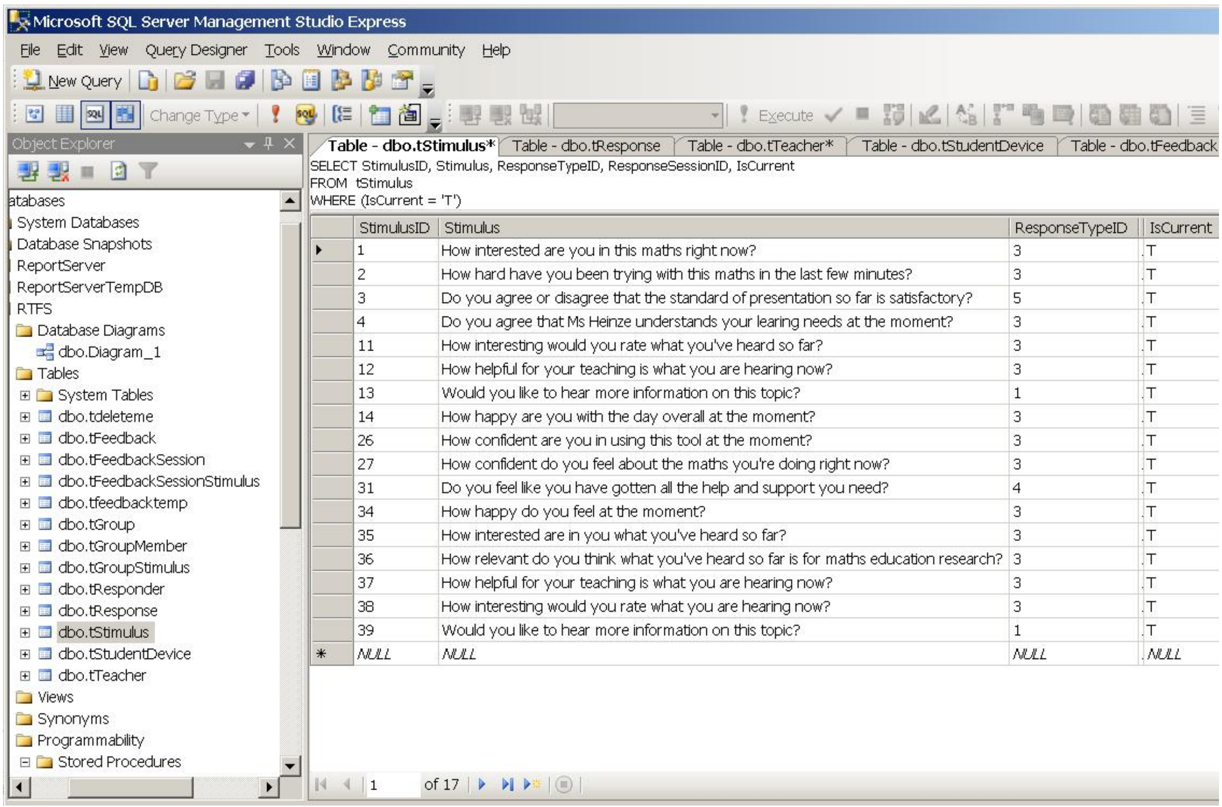
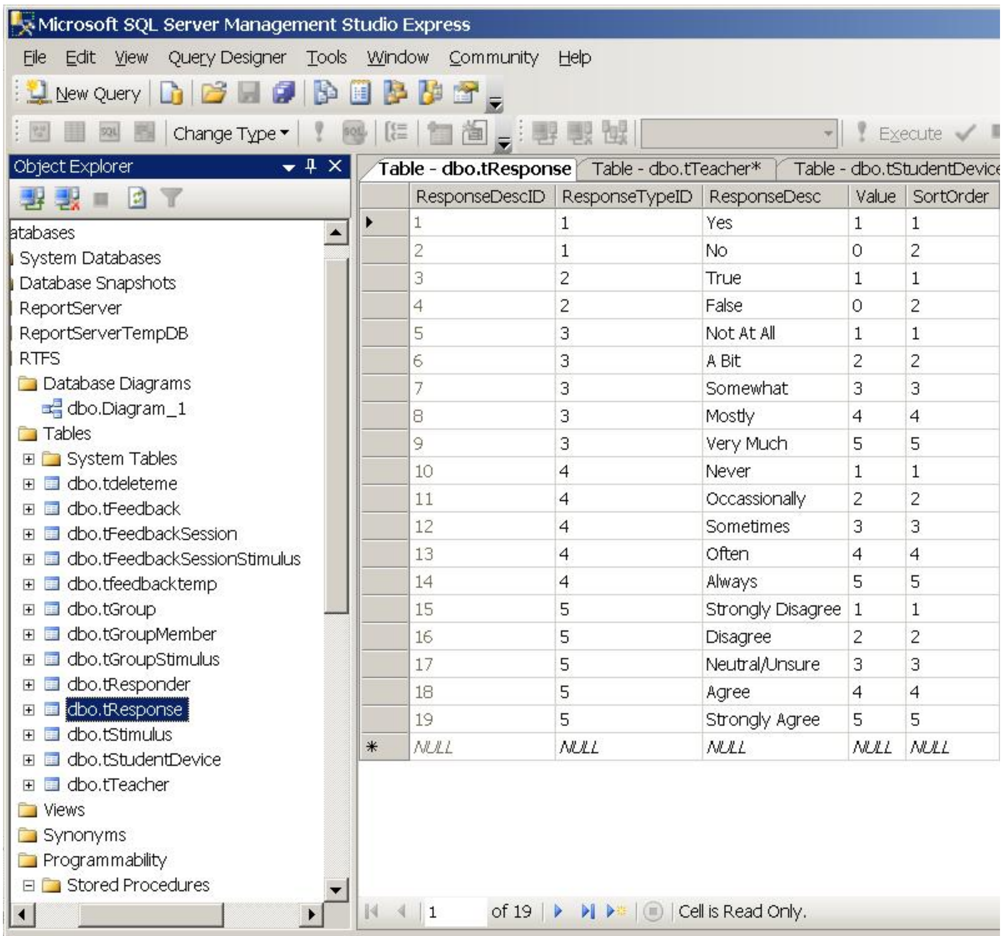


Figure 3.5. Sample data from table tStimulus.

3.1.4.3 ResponseTypeID

The last table to be discussed in this chain of data arising from student responses to questions is tResponse, shown in Figure 3.6. This contains the text of the actual Likert responses for each question. For instance, the question “How interested are you in this maths right now?” in tStimulus with StimulusID = 1 is associated with a ResponseTypeID of 3. It can be seen in Figure 3.6 that this corresponds to a five point Likert scale of “Not At All”, “A Bit”, “Somewhat”, “Mostly”, “Very Much”. Each of these rows in tResponse have a ResponseTypeID of 3, and numerical values ranging from 1 to 5. It is this Value figure that is recorded in tFeedback as ResponseValue. The ResponseDescID in tResponse merely provides a unique Primary Key value for each entry in the table, while the SortOrder column provides the RTFS with a way to put determine the sequence in which to display each of the response options.



ResponseDescID	ResponseTypeID	ResponseDesc	Value	SortOrder
1	1	Yes	1	1
2	1	No	0	2
3	2	True	1	1
4	2	False	0	2
5	3	Not At All	1	1
6	3	A Bit	2	2
7	3	Somewhat	3	3
8	3	Mostly	4	4
9	3	Very Much	5	5
10	4	Never	1	1
11	4	Occassionally	2	2
12	4	Sometimes	3	3
13	4	Often	4	4
14	4	Always	5	5
15	5	Strongly Disagree	1	1
16	5	Disagree	2	2
17	5	Neutral/Unsure	3	3
18	5	Agree	4	4
19	5	Strongly Agree	5	5
NULL	NULL	NULL	NULL	NULL

Figure 3.6. Sample data from table tResponse.

So it can be seen that each record in tFeedback captures data that link to records in other tables. It is important to understand these relationships in order to build database queries that retrieve data in a number of useful ways. It is the role of the RTFS application to manage these queries, writing submitted data into the appropriate tables, and using retrieved data to generate dynamic web pages that contain relevant content.

3.1.5 The RTFS application

The RTFS application itself consists of a set of around 40 ASP pages which control the flow of data between the IIS web service and the SQL Server database service. Relationships exist between each of the pages so that they *call* each other to perform specific actions. In this way they are like discrete functions that can be called by a main programming routine. However, because they are web pages, they can contain both display and programmatic elements. With the advent of Cascading Style Sheets and ASP compilers there is a move within software development toward separating these two types of elements into completely different entities. This makes for applications which are easier to maintain, more secure, and consequently more robust, however, for my purposes there was little to be gained in putting energy into this approach given the RTFS was being developed for an offline environment by a single programmer.

3.1.5.1 The main screen

The RTFS contains several distinct sections; Configuration; Session Setup; Data Collection, and; Data Review. The configuration interface was used to load basic information about the teachers who used the tool, their class lists, the group categories they nominated, and allow the allocation of particular iPods to particular students as well as specifying which group the teacher had assigned them to. The session setup interface allowed teachers to write their own questions and choose the type of responses they wished students to provide to these questions. The data collection interface simply activated the RTFS to start prompting and recording feedback from connected devices. The audio recording software needed to be activated separately. Last, the data review section allowed teachers to view their students' responses in a graphical format either as a whole class, by group, or individually. The following six figures, Figures 3.7 – 3.12, illustrate some of these basic screens.

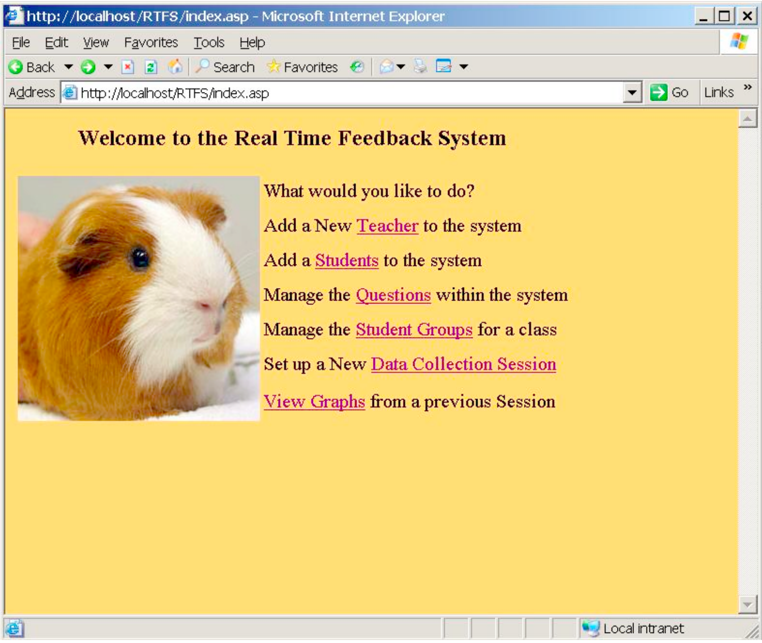


Figure 3.7. Main screen for accessing the RTFS functionality.

The start screen, or main control screen, shown in Figure 3.7 is the entry point to the RTFS for teachers. It allows teachers to access the various other functions of the RTFS. The first option allows new teachers to be added to the system, although this functionality was incorporated more for my benefit than the teachers. Nevertheless, it was thought possible that other colleagues might wish to use the sytem themselves, so this made it easy for new teachers to be registered within the system should the need arise.

3.1.5.2 Student management

The second option allowed teachers to add and edit student details via the screen illustrated in Figure 3.8. First they chose their class from the dropdown list, which triggered the system to populate the large multi-select box below with existing student details (note that the data in the figure has been blurred to preserve anonymity). Additional students could be added by entering their details above the large multi-select box and clicking ADD.

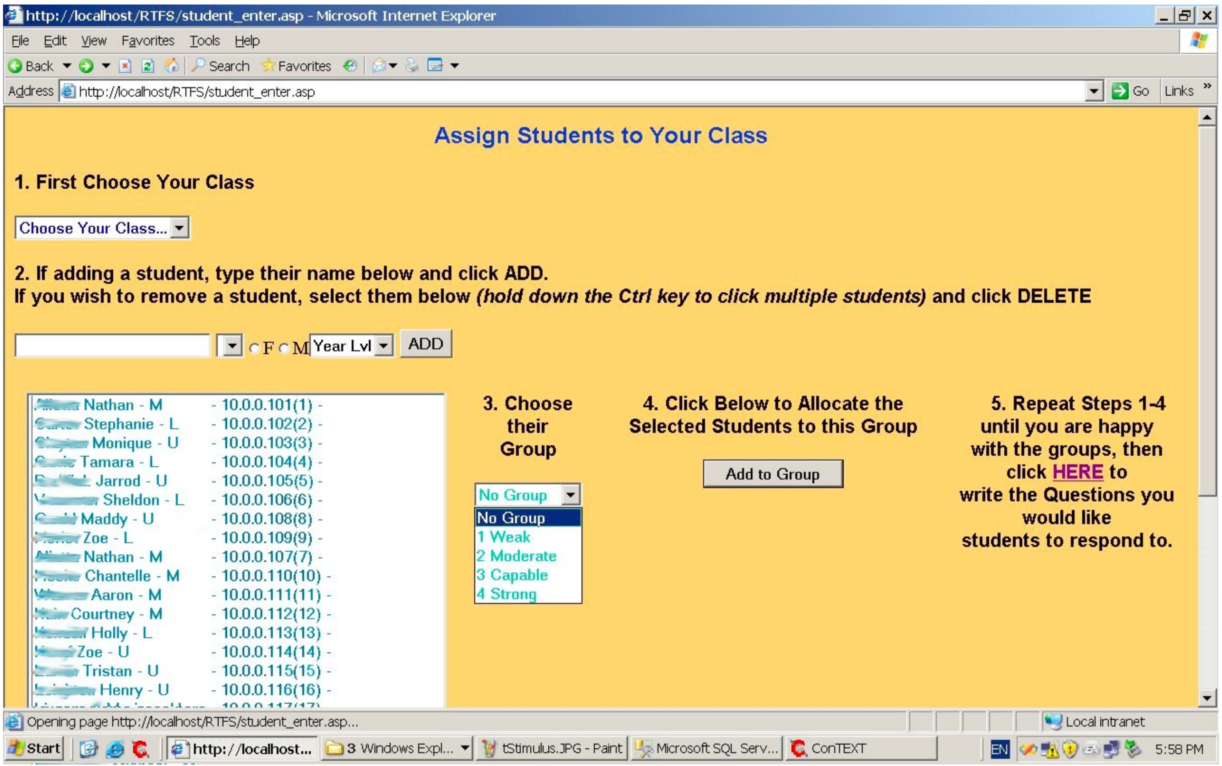


Figure 3.8. Screen for adding student details to the RTFS database.

Once a student had been added and allocated a group by the teacher their name would display a capital letter suffix corresponding to their group, as can be seen above. The teacher could further manage group allocation by selecting one or more student names, choosing the appropriate group from the adjoining dropdown box, and clicking the Add to Group button. This would refresh the list of names accordingly.

The RTFS application would automatically assign an iPod Touch to each student as they were entered, which would then dictate which student was to be given which device.

3.1.5.3 Question management

Once the class list was complete, teachers could proceed to the question management screen shown in Figure 3.9. Here they could write new questions and allocate one of five response types to each question. They could then specify which questions were to be used, and whether they were to be used with specific groups of students. Those not being used would have a *Not Being Used* prefix. The groups specified by the particular teacher would appear in the small box below the larger multi-select box.

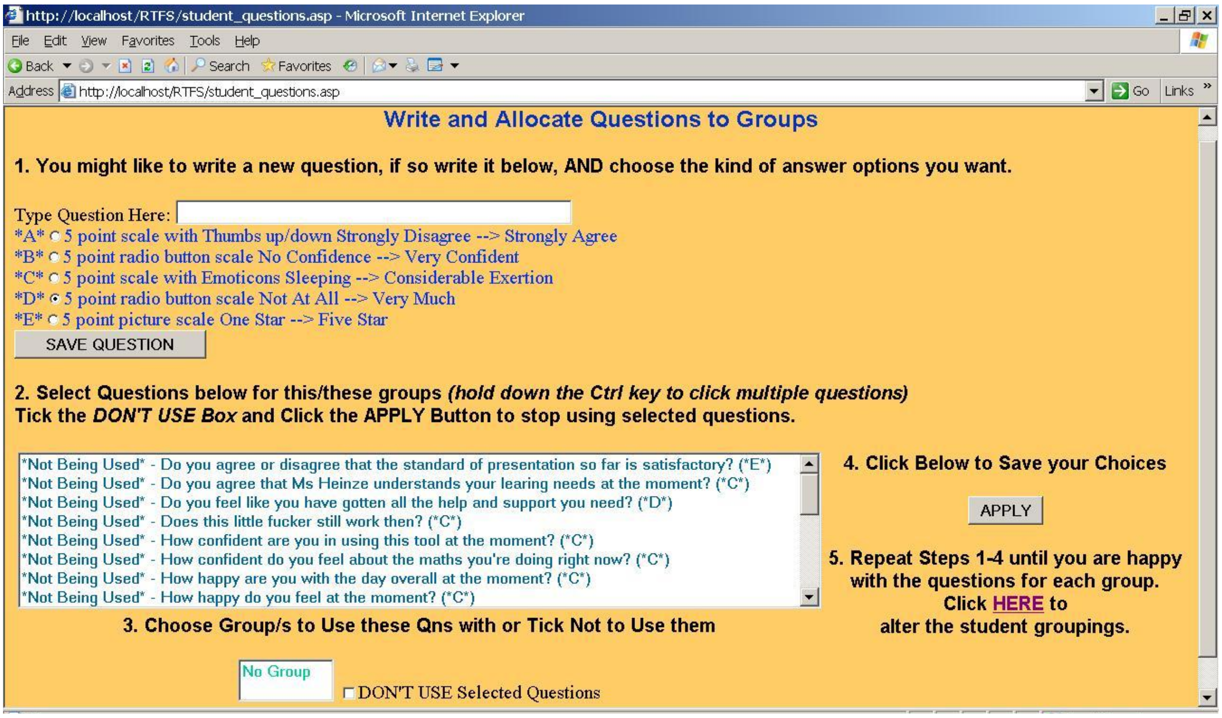


Figure 3.9. RTFS screen for writing questions and specifying types of response.

3.1.5.4 Data collection

Once a teacher had entered their students and decided on the questions they wished to use there would be no need to revisit these screens for subsequent data collection sessions unless they wished to make changes. To use the RTFS with their class they would simply choose their class from a dropdown box, type in the date of the session, and click the save button as shown in Figure 3.10. Students would then be able to browse the RTFS website using their iPod Touches and begin providing responses to the teacher's questions.

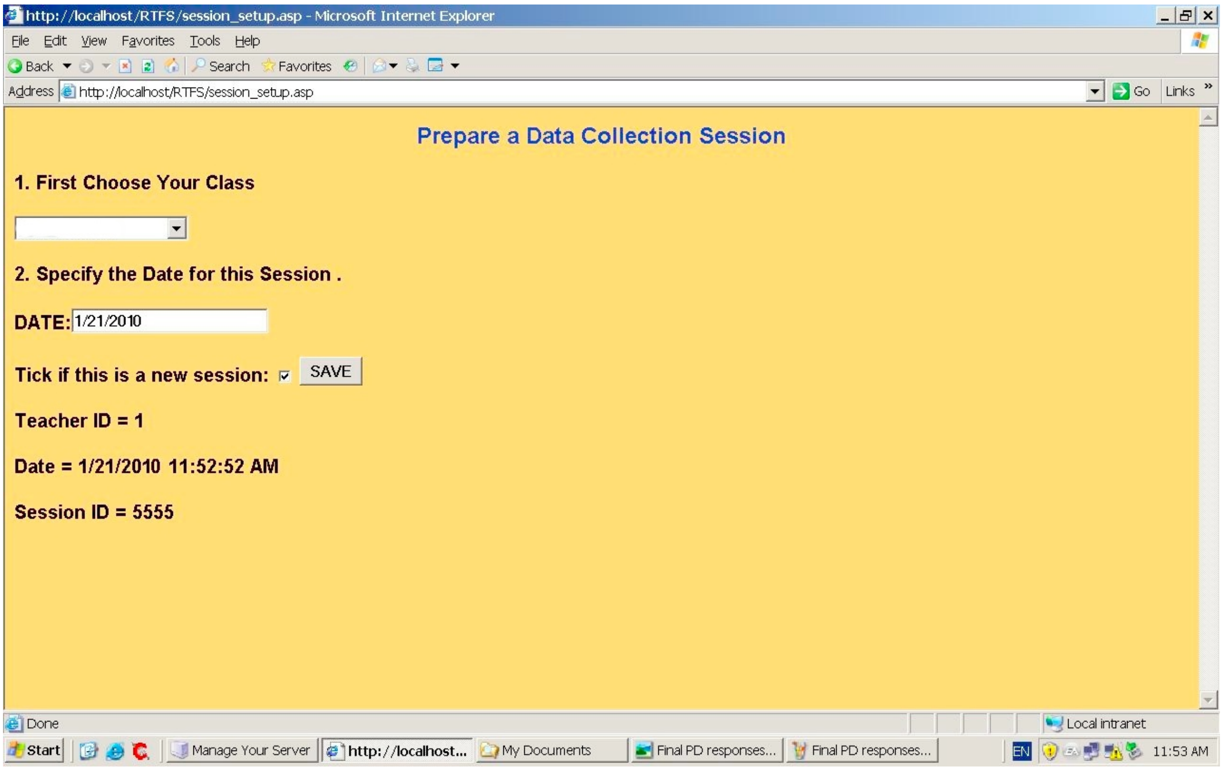


Figure 3.10. The RTFS screen used to activate data collection.

3.1.5.5 Viewing feedback

After, or even during data collection, teachers could view the graphically rendered feedback. To do this they would click on the radio button signifying the relevant session they wished to examine from the list of available sessions and click on the Show Graph button, as seen in Figure 3.11.

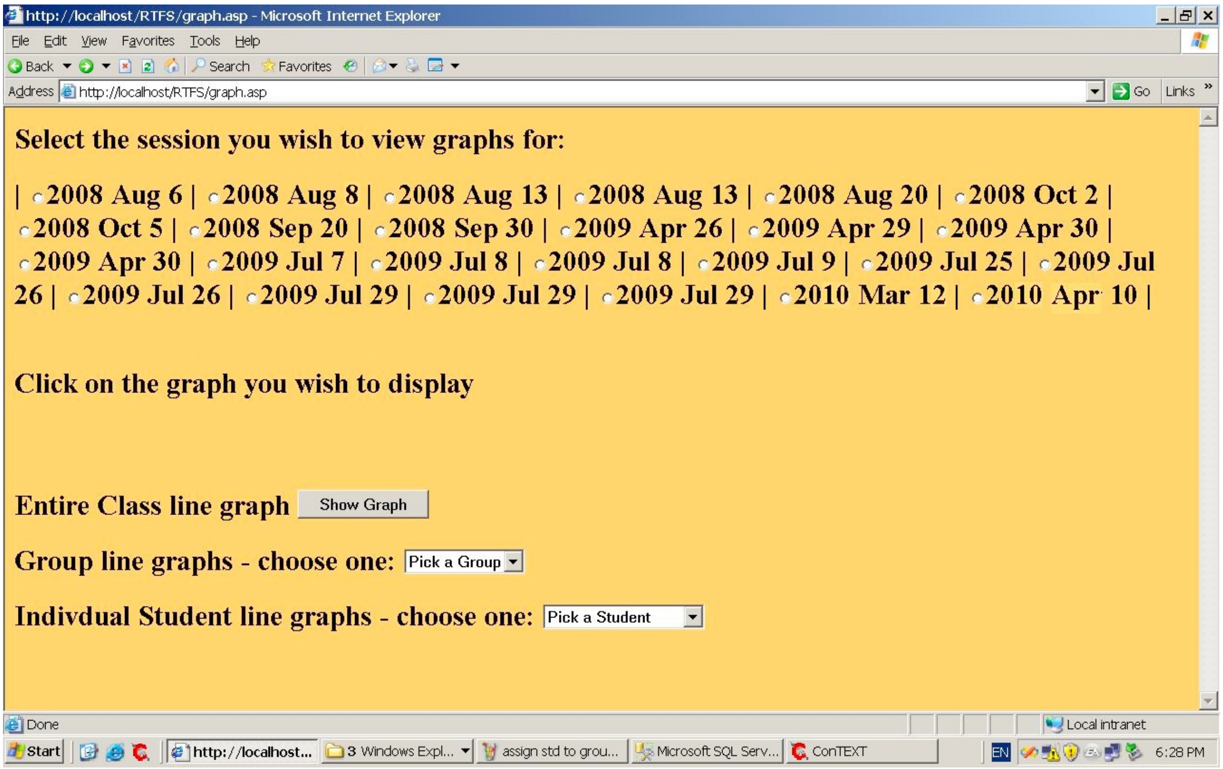


Figure 3.11. RTFS screen for selecting the session for which to view feedback.

Teachers could also choose to see graphs for groups of students, or individual students, by selecting one of these from the two dropdown boxes available. The resulting graphs are generated by a plug-in IIS compatible applet, Fusion Charts, which utilizes Javascript to generate an animated line graph image from a properly formatted Extensible Markup Language (XML) data set passed to it by the RTFS application.

3.1.5.6 Feedback graphs

A typical whole of class graph is shown in Figure 3.12. The responses of each student are plotted along a quasi-time axis in a distinct colour. Colours are allocated randomly, excluding shades of red which is reserved for the calculated Average Response line. The time axis is actually a grouping of responses within a specified time interval which was necessary due to technical limitations of the Fusion Charts applet. The next section provides a brief insight into the kinds of decisions that were necessary during the development process to arrive at a functional web application.

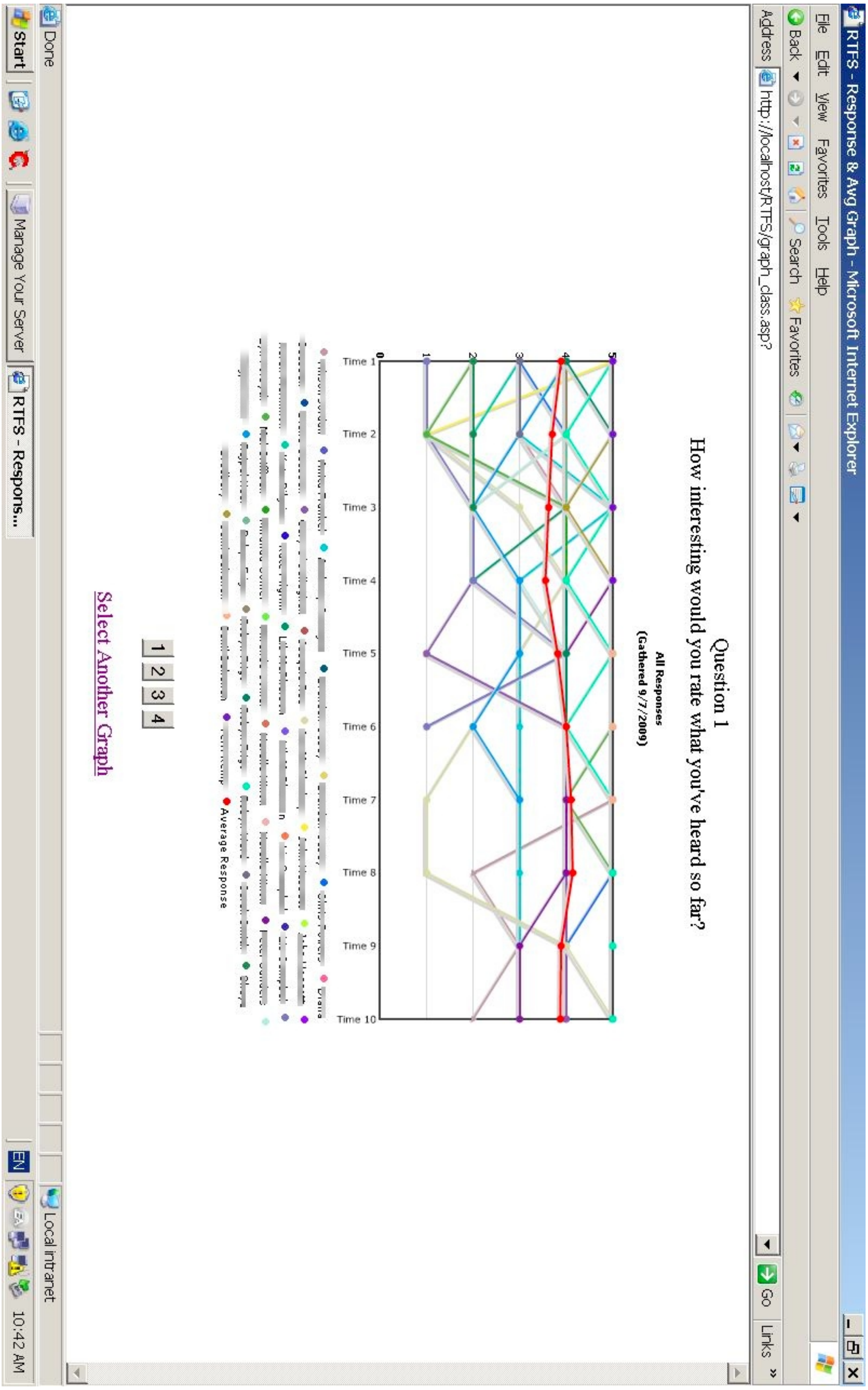


Figure 3.12. Sample RTFS whole class graph (anonymised).

3.1.6 Overview of data flow within the RTFS application

This section briefly describes the process of recording user input into the database. Within the RTFS there are many situations where data is written to the database, all of which depend on the kinds of data relationships outlined earlier, however virtually all of these inputs are designed to support the key function of recording student responses to teacher questions, so the way in which this is achieved by the RTFS is explored in some detail below.

Students connect to the RTFS website by tapping an icon button the home screen of the iPod Touch. This automatically opens the Safari browser and navigates to the appropriate web address (http://10.0.0.1/start_here.asp). Numerous data are embedded with the request to the server to send this start page to the device. This is a standard part of every website interaction, since when a user submits a request of any kind over the internet, the server they are contacting requires the unique IP address of the requesting computer to ensure the response is directed back to the appropriate client. When students submit data to the RTFS application the IP address of their iPod Touch is included as part of the data transmitted.

Once the data stream is received by the RTFS application, the IP address is used to search the tResponder table to find the corresponding student's ResponderID. This is then written to the tFeedback table along with the details of the question they are responding to (StimulusID) and the value of their actual response (ResponseValue). It is the IP address recorded in tResponder which allows the RTFS to identify which student is providing which response.

3.1.7 Examples of development decisions and difficulties

The development process consisted of many technical quirks and difficulties that needed to be overcome in order to produce a functional piece of software. This section attempts to give a taste of some of the thought processes and experimentation that was required to overcome these difficulties. It also provides some sample code from the RTFS itself.

In the first RTFS prototype it became evident that there were dropouts in connections between student iPods and the database/web server. When a client device first establishes contact with an ASP application the IIS ASP service allocates a unique session variable to the connection, which can be accessed programmatically to identify individual clients. These session variables have a specified lifespan, with a default setting of 20 minutes. After 20 minutes of inactivity the client's session is dropped, and any further communication with that client is issued a new session variable. When the ASP session timed out for certain students, multiple entries would appear in table tFeedback for the same students as if they were different students.

This bug was corrected by abandoning the use of ASP session variables as the unique identifier and instead ensuring that all data entries from the same IP address for the same data collection session were allocated the same ResponderID, effectively using the device IP address as the unique identifier instead. This entailed that each iPod had to be allocated a static IP address instead of relying the DHCP service to dynamically allocate an address. This also made it possible to identify students by allocating specific devices to specific students on the class roll.

There was no value in rewriting the relevant ASP code to use IP addresses instead of the unique ResponderID, it was more efficient to simply unify all the ResponderID's in tFeedback. This was achieved through writing a simple stored procedure in the database itself, sp_Combine_Identical_Responders_Feedback shown in Figure 3.13 which allocated the same ResponderID to any line of data from the same device.

```sql
CREATE  PROCEDURE [dbo].[sp_Combine_Identical_Responders_Feedback]
                  @FeedbackSessionID int, @TeacherID int
as
BEGIN
  DECLARE @DataCount int, @NewRow varchar(100), @LastReturn int,
  @ResponderID int, @StimulusID int, @Date char(20),
  @ResponderIDold int, @DeviceIP varchar(15), @DeviceIPold
  varchar(15), @FeedbackID int, @MinAdd int

  --NOTE: this procedure corrects ResponderID discrepancies arising
  from dropped
  --connections by allocing the first ResponderID for all identical
  IP addresses.
  --It is called using
  --"EXEC sp_Combine_Identical_Responders_Feedback 154, 33" to
  combine IP's for
  --data collection session 154 & Teacher 33

   SET @ResponderIDold = 0
   SET @DeviceIPold = 0
   DECLARE responder_cursor CURSOR FOR
       select responderid, deviceidentifier from tresponder
       where classid = @TeacherID and feedbacksessionid =
@FeedbackSessionID
       order by deviceidentifier, responderid
   OPEN responder_cursor
   SET @DataCount = @@CURSOR_ROWS
   WHILE @DataCount > 0
   BEGIN
       FETCH NEXT FROM responder_cursor
       INTO @ResponderID, @DeviceIP
       IF @ResponderID <> @ResponderIDold AND @DeviceIP =
@DeviceIPold
       BEGIN
               UPDATE tFeedback SET ResponderID = @ResponderIDold
         WHERE ResponderID = @ResponderID
       END
       ELSE IF @DeviceIP <> @DeviceIPold
       BEGIN
         SET @ResponderIDold = @ResponderID
         SET @DeviceIPold = @DeviceIP
       END
     SET @DataCount = @DataCount - 1
   END
   CLOSE responder_cursor
   DEALLOCATE responder_cursor
END

--exec [dbo].[sp_Combine_Identical_Responders_Feedback] 5000, 4
```

Figure 3.13 Stored procedure written to unify disparate data arising from dropped connections.

Once the data were stored coherently, it was necessary to be able to produce graphical output in a web page. I first explored doing this via a table using straight Hyper Text Markup Language (HTML) and Cascading Style Sheets (CSS), however these produced less than ideal outputs when data from more than around ten students were to be presented. Further research turned up the freeware flash product, Fusion Charts, which provided clean graphical outputs for around 20 students simultaneously. However, as mentioned previously, the format of acceptable inputs into the Fusion Charts applet required that there could be no gaps in the data stream, that is, if three students (1, 2, & 3) responded with Likert values 5, 4, 3 at times 5, 6, and 7 respectively, then the XML data set for these would look something like this;

```
<set studentID='1' time='5' value='5' color='8E468E'/>
<set studentID='2' time='6' value='4' color='008ED6'/>
<set studentID='3' time='7' value='3' color='A186BE'/>
```

However, Fusion Charts could not accommodate gaps in the data stream, thus these data would have to be formatted along the following lines to fill in responses for each time point to be graphed;

```
<set studentID='1' time='5' value='5' color='8E468E'/>
<set studentID='1' time='6' value='5' color='8E468E'/>
<set studentID='1' time='7' value='5' color='8E468E'/>
<set studentID='2' time='5' value='4' color='008ED6'/>
<set studentID='2' time='6' value='4' color='008ED6'/>
<set studentID='2' time='7' value='4' color='008ED6'/>
<set studentID='3' time='5' value='3' color='A186BE'/>
<set studentID='3' time='6' value='3' color='A186BE'/>
<set studentID='3' time='7' value='3' color='A186BE'/>
```

This produced graphs that looked like the one shown in Figure 3.14, where it is impossible to distinguish between the actual responses from students and the interpolated responses. The overlapping lines also obscured each other to a far greater extent than was acceptable for ease of interpretation.

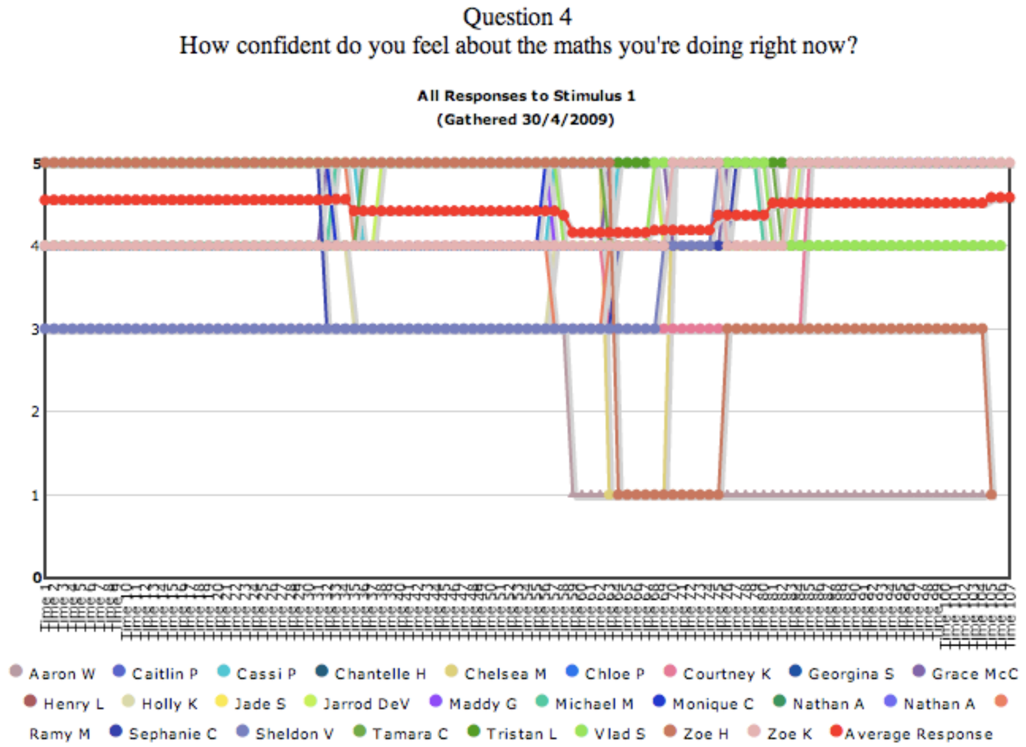


Figure 3.14 Sample graph resulting from using actual and interpolated response times.

Instead, I decided to use time slices as the reference points rather than the individual timestamps of each response. In this way responses from students that were recorded within a five minute period would be treated as having been recorded simultaneously. This loss of time resolution dramatically improved the display properties of the graph, as can be seen in Figure 3.15, where the same data are presented in this time slice manner. Experimenting with the size of the time slice showed that five minutes produced the greatest clarity of output. There was still overlapping of lines, but the red average line combined well with the individual lines to make for a graph considerably easier to read than the one produced using interpolated data points.

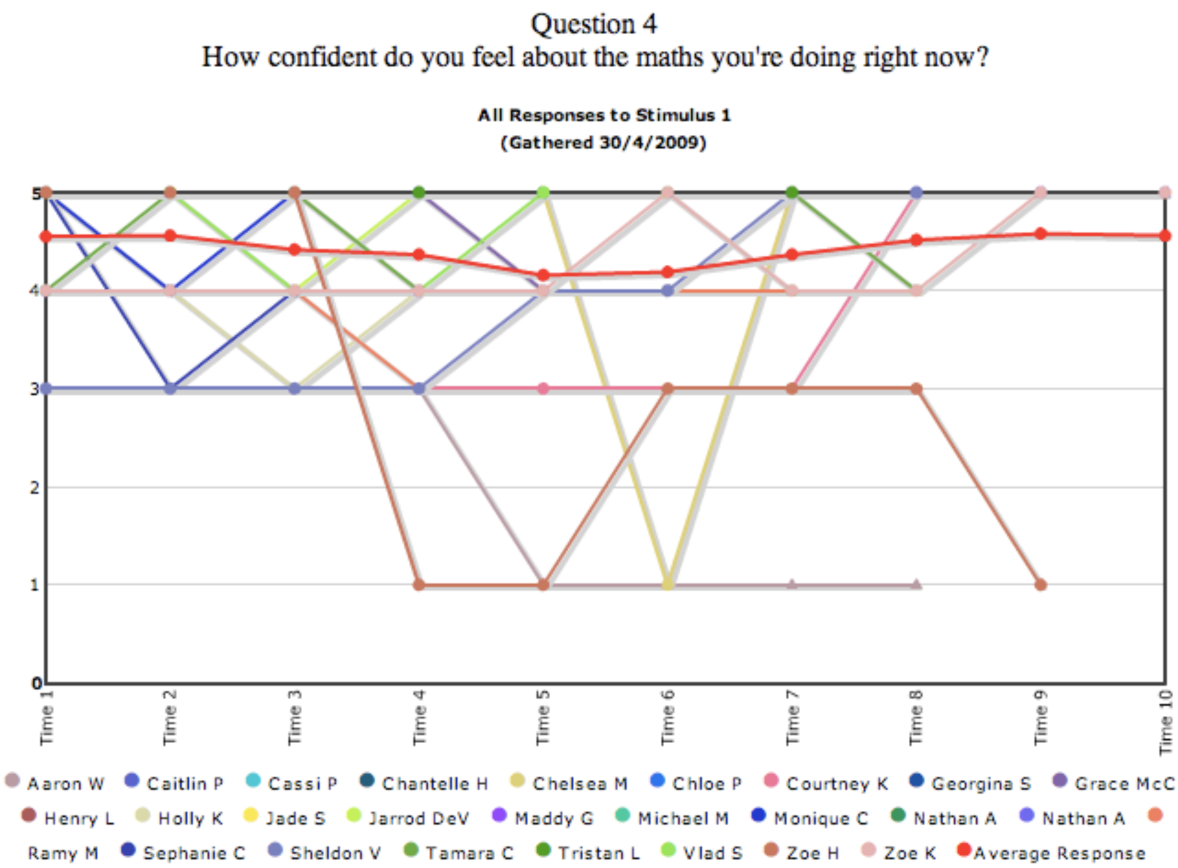


Figure 3.15 Sample graph grouping responses into five minute time slices.

The other decision made to improve the visual utility of the graph was to include an average calculation that covered each time slice. However achieving these outcomes was not straight forward.

To generate the necessary XML data set it was necessary to identify the first and last responses in the data collection session and to then loop through all of the records to create the appropriately sized x-axis. This meant it was necessary to calculate the number of minutes that had elapsed from the start of the data collection session for each response that had been recorded. Given that each response in tFeedback contained a timestamp (FeedbackDate) it should have been possible to calculate the amount of time using a nested SQL statement that retrieved this information:

```
SELECT MAX(DATEDIFF(mi, CONVERT(datetime, SELECT MIN(FeedbackDate)
                                   FROM tFeedback
                                   WHERE FeedbackSessionID = 5000,
                                   121), FeedbackDate)))
FROM tFeedback
WHERE FeedbackSessionID = 5000 and DATEDIFF(mi, CONVERT (datetime,

                                   SELECT MIN(FeedbackDate)
                                   FROM tFeedback
                                   WHERE FeedbackSessionID = 5000,
                                   127), FeedbackDate) < 120;
```

However, while this SQL statement ran fine within the database query tool, when incorporated into the relevant ASP page they triggered a *recordset closed* error. It took some time to discover that it was the multipart nature of the statement that caused the problem. Strangely the query ran perfectly within ASP when stored as in a text variable (strSQL) and executed on its own as a *connection object* execute statement (objCN.execute strSQL), but failed when incorporated into the opening of a *record set object* (objRS.Open or SET objRS = objCN.execute(strSQL)).

The problem was resolved by splitting the query up into its constituent parts and retrieving minimum and maximum times into ASP variables. However, this led to an even more peculiar situation when attempting to calculate the time elapsed by constructing the SQL query in ASP and using an ASP variable (FirstResponse) to store the datetime value of the first response and incorporating this into the relevant section of the dynamically constructed DATEDIFF function call:

```
strSQL =    "SELECT MIN(FeedbackDate) as FirstResp " &_
       "FROM tFeedback WHERE FeedbackSessionID = " &_
       Session("sv_GraphFeedbackSessionID")
objRS.Open strSQL, objCN
       FirstResponse = objRS("FirstResp")
objRS.Close
strSQL =    "SELECT MAX(DATEDIFF(mi, CONVERT(datetime,'" &
       FirstResponse & "',121),"&_ "FeedbackDate)) as NoMin FROM
       tFeedback WHERE FeedbackSessionID = " &_
       Session("sv_GraphFeedbackSessionID") & " and DATEDIFF(mi, " &_
       "CONVERT(datetime,'" & FirstResponse & "',127), feedbackdate)<120"
```

However, this produced an error from the ODBC layer due to a failure to successfully convert the date component of the character variable strSQL into a datetime data type:

Microsoft OLE DB Provider for ODBC Drivers error '80040e07'
[Microsoft][ODBC SQL Server Driver][SQL Server]Conversion failed when converting datetime from character string

Substituting the CAST function in place of the CONVERT function failed in a similar way, regardless of the resolution level selected (yyyy-mm-dd hh:mi:ss 24 hour time with seconds or yyyy-mm-dd hh:mi:ss.mmm 24 hour time with milliseconds), nor did stripping away the date element and reducing the data to hh:mm:ss:m format work. Each approach kept producing date strings of the form dd/mm/yyyy h:mm:ss am/pm which continued to be rejected by the SQL engine. After a considerable amount of fiddling around in trying to get this approach to work, I was eventually successful by casting the converted date back into a char datatype, and wrapping the resulting output in quote marks. Counterintuitively this generated date data of the form Apr 30 2009 8:39AM which the SQL engine parsed this back into datetime data after having been stored and transferred as an ASP char datatype. The resulting code is as follows:

```
strSQL = "SELECT " &_
         "CAST(CONVERT(datetime, MIN(FeedbackDate),120) as char)" &_
         " as FirstResp " &_
         "FROM tFeedback WHERE FeedbackSessionID = " &_
         Session("sv_GraphFeedbackSessionID")
objRS.Open strSQL, objCN
         FirstResponse = "'" & objRS("FirstResp") & "'"
objRS.Close
strSQL = "SELECT MAX(DATEDIFF(mi, CONVERT(datetime," &_
       FirstResponse & ",121), FeedbackDate)) as NoMin " &_
       "FROM tFeedback WHERE FeedbackSessionID = " &_
       Session("sv_GraphFeedbackSessionID") &_
       " and DATEDIFF(mi, " &_ "CONVERT(datetime," & FirstResponse &_
       ",127),feedbackdate) < 120"
```

Had this approach failed it would have been necessary to explore adding an additional column to tFeedback to capture the number of minutes that had elapsed at the time of the response, and expanding the functionality of the stored procedure discussed earlier to calculate this value and update these data at the completion of the data collection session. However, this would have merely shifted the burden of solving the identical problem to a different process, one of the downsides of which would have been the need to manipulate data prior to graphing, going against the notion of real time feedback, and imposing a performance penalty by increasing the required calculations prior to producing graphical outputs. This approach would have been particularly inefficient given that while such a procedure would be nondestructive after the initial collating of responses, the subsequent nett functionality of rerunning the procedure would have been zero, and as a general rule it is undesirable to run code for no reason after it has performed its one function. This could have been worked around by setting a flag to inhibit any subsequent triggering of the procedure, but doing so would merely add to the complexity of the code, thereby making maintenance more difficult.

Many problems along these lines were encountered during the development of the RTFS tool, and there were also a considerable number of technical and logistics problems associated with the hardware, for instance: resolving difficulties around limiting the functionality of the iPods to a chosen set of features: developing a system to keep the class set of iPods charged; implementing a practical solution for transporting all of the equipment that facilitated portability and provided secure storage between sessions whilst minimising set up time; enabling easy identification of individual iPods; overcoming difficulties with installing an operating system designed for desktop servers on a laptop, particularly with respect to obtaining suitable hardware drivers; securely configuring the WiFi router; implementing a reliable version control process; implementing a reliable backup regime; automating and streamlining as many functions as possible to minimise teacher input from those wishing to use the RTFS unassisted.

While the RTFS was fully functional, there remained considerable scope for further refinement and development. The change in focus of my research necessitated the curtailment of this process, but it would be easy enough to recommence the process at a future time if circumstances warranted it. Having given a flavour of the development phase of the project I now turn to some of the results that were garnered from it.

3.2 *Using the RTFS: Reflective teaching case studies*

Having developed a tool for teachers to use it was then necessary to put it to the test. A brief presentation outlining the nature of the tool was given at one of the first TTML teacher conference days. Teachers who indicated a willingness to be involved in classroom observations on the survey administered at that time were subsequently approached and invited to participate in trialling the RTFS. In total seven teachers agreed to trial the RTFS, although only five ended up doing so.

3.2.1 The RTFS and teacher reflection

A number of case studies were undertaken with teachers using the RTFS. In each of these the teachers either selected or provided questions of interest to themselves while I set up the equipment and familiarised students with how to use the iPod Touches. At the end of the lesson the teachers took part in a semi-structured interview whilst reviewing the collected data. The main research question behind the interviews was to investigate the extent to which teachers engaged in professional reflection, and how useful the RTFS was in stimulating such reflection.

The analysis of these interviews with teachers suggested that they quickly moved beyond Van Manen's (1977) notion of technical reflection toward the more ideal critical reflection, however it was possible to read their reflections in a less generous light. The teachers reported that they saw considerable potential for the use of the RTFS to help improve their pedagogical practice, and even made suggestions/requests for how it could be further enhanced.

After modifying the RTFS to incorporate these suggestions, opportunities were given to teachers to use the equipment themselves. The kit was left with three teachers for several weeks with the offer of immediate support via email or mobile phone should they require it. After each of these loan periods none of the teachers had managed to 'get around' to using it. This started to raise doubts in my mind as to how realistic it was to expect teachers to adopt new technology in what is already a very busy workplace. In turn this led me to reflect on the way in which the reflections I had captured in interviews appeared to be highly professional and student centred on the one hand, yet arguably no more than technically reflective if read from other perspectives (e.g., Day, 1993; Tremmel, 1993; Valli, 1997; and Zeichner & Liston, 1996).

Some of the divergence in opinions relating to professional reflection may arise from a difference in emphasis depending on the broader area of investigation the reflections are associated with. Because there is considerable interest in teacher reflection as a form of ongoing professional learning, their nature and the techniques used to elicit these reflections from teachers have been explored across a wide range of research interests within mathematics education, such as professional learning generally, specific reflection practices, and teacher change.

3.2.2 Professional learning

Muir and Beswick (2007) conducted an extensive review of the professional learning literature and derived three main themes or principles of effective approaches to professional learning:

- Professional learning is more likely to be effective if it addresses teachers' pre-existing knowledge and beliefs about teaching, learning, learners and subject matter.
- Professional learning is more likely to be effective if it provides teacher with sustained opportunities to deepen and expand their content and pedagogical knowledge.
- Effective professional learning is grounded in teachers' learning and reflection on classroom practice. (pp. 75-6)

The TTML project engaged teachers in all three of these dimensions, however the focus of this thesis was exclusively on the first and third items only. In this study teachers were invited to compose a set of prompts or questions for which they were interested in obtaining feedback from their students. The teachers were encouraged to devise prompts that covered areas of interest to themselves, which provided an opportunity for them to explore aspects of their existing pedagogical practices, attitudes and/or beliefs. These prompts were then loaded into the RTFS so the teacher could collect data from their own classrooms and reflect upon the results.

To some extent the first item is subsumed by the third in that reflecting on ones' own practice automatically incorporates and addresses ones' existing knowledge, beliefs, and attitudes to teaching, learning, and students. When reflection becomes an ongoing part of a teacher's practice it would have the potential to address all three areas comprehensively. In this way it was envisaged that the RTFS could be used to intermittently focus teachers attention on aspects of their classroom that they did not normally have access to. The intention was that doing so would directly address teachers' existing knowledge and beliefs, deepen their pedagogical knowledge, and would be fully grounded in their classroom practice.

3.2.3 Teacher reflection in the literature

Encouraging teachers to reflect on their practice is a strong theme in the professional learning literature. Dewey (1933) called for teachers to engage in "reflective action" early in the 20th Century. He argued that teachers should adopt three attitudes he identified as prerequisites to reflection: wholeheartedness; responsibility; and open-mindedness. A teacher might be forgiven for thinking of these prerequisites as somewhat idealistic. For instance, responsibility is described as taking account of the personal, intellectual, and social consequences of every pedagogical decision a teacher makes on each of their students. However, in setting up an ideal Dewey (1933) gave form to an alternative understanding of teachers as facilitators and guides rather than authoritarian deliverers of pre-ordained knowledge (Kirschner, Sweller, & Clark, 2006).

In a similar vein Zeichner and Liston (1996) delineate between the historical view of teachers as passive technicians and Zeichner and Liston's (1996) notion of the reflective teacher. For them a reflective teacher "questions the goals and values that guide his or her work, the context in which he or she teaches…[and] examines his or her assumptions" (p.1). They contrast this with the view of teachers as technicians delivering programs conceived of by others, located elsewhere.

Rather than passive consumers of curriculum, Zeichner and Liston (1996) see teachers as experts who understand the constraints and complexities of teaching due to their direct involvement in their classrooms. That is, unlike external researchers, teachers possess what Schön (1983) described as *knowledge-in-action*, by virtue of the very act of teaching. Schön (1983) goes further and claims that because of its implicit, spontaneous, and unconscious nature, knowledge-in-action is largely inaccessible to researchers, creating a disconnect between the "high ground" world of external research and the problems teachers face in the "swamp" of their classrooms. This mirrors Pike's (1967) emic/etic distinction discussed earlier, and reinforces the need for any change in practice to be grounded in the reality of the classroom. Again, this is where the RTFS was intended to excel by being a tool used by teachers to explore issues of concern to themselves and to stimulate professional reflection that could bring about pedagogical change.

3.2.4 Teacher change in the literature

Teacher change arising from their classroom experiences is central to Guskey's (1986) linear model of change. Guskey (1986) suggests that changes to teachers' beliefs and attitudes resulted from them observing changes in student learning which arose from the teachers implementing changes in their classroom practices (see Figure 3.16).

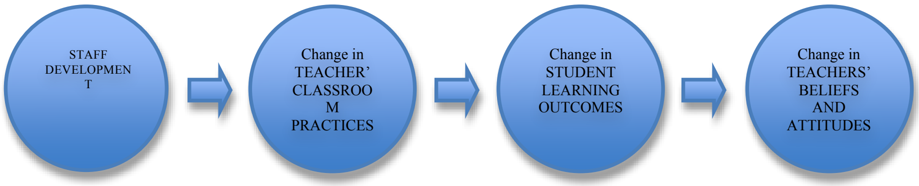


Figure 3.16 Guskey's (1986) model of the process of teacher change (p. 7).

This model is largely consistent with Schön's (1983) reflective practice in that change stems from teachers' classroom experiences and observations. There are two key differences, however. Guskey (1986) posits changes being initiated through a process of, largely external, staff development and ending with a change in teachers' beliefs and attitudes. By contrast Schön's (1983) reflective practitioner would be providing their own, largely internal, staff development opportunities through reflection on their own classroom practices which would in turn bring about a shift in their beliefs and/or attitudes in a cyclical fashion (see Figure 3.17.).

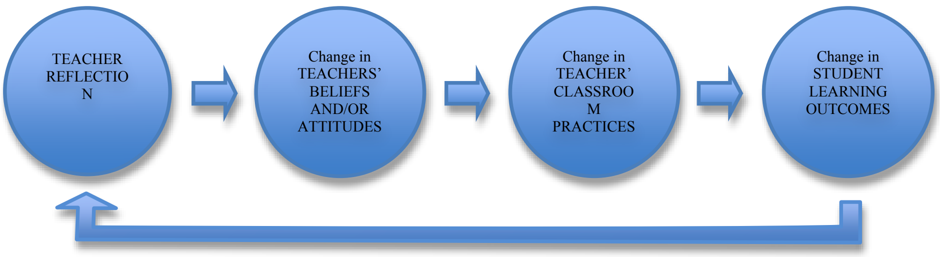


Figure 3.17 A model of the reflective practitioner's change based on Schön (1983).

Crucially, Guskey (1986) identifies the impetus for change as an external source whilst for Schön (1983) it is an internal one. Feiman-Nemser (2001) offers a middle way for teacher change and professional learning by casting teachers in the role of researcher; videotaping and analyzing their own and colleagues classes, interviewing students, and examining samples of student work. Such an approach utilises externally developed methods to prompt internal reflection.

This thesis adopts a similar position to Feiman-Nemser (2001) by placing an externally sourced research tool into the hands of teachers to facilitate their internal reflection. In this way the study sought to ascertain whether such a merging of these 'first steps' (external and internal) through use of the RTFS was able to stimulate the kind of reflection that might lead to attitudinal and pedagogical changes. This approach seems to cohere with important principles identified in the professional learning, teacher reflection, and teacher change literature, and I will now describe the process of how the RTFS was actually used with teachers.

3.3 *An RTFS case study*

In this thesis TTML participants were provided with an electronic data collection tool, the Real Time Feedback System (RTFS) described above and in O'Donovan (2008). The RTFS enabled these teachers to pose a set of questions that each of their students would view and respond to during a mathematics lesson using iPod Touches. The collected data were available in graphical format for the teacher to review at the end of each lesson in a semi-structured interview.

The change that occurred in the focus of this thesis rendered much of the collected data, and the RTFS, largely redundant. So rather than presenting multiple case studies this section focuses on the details of one illustrative case study, and where relevant supplements the individual case study with data from other cases to demonstrate themes that were found across the board, particularly those which led to the change in focus of the thesis.

For this case background data are provided about the teacher and school and then the results are presented and discussed. This case study is based upon the second occasion that the class had used the RTFS, so the students were already familiar with the devices, how to operate them, and what was expected of them. It was, however, the first time the teacher had reviewed the graphical feedback because the first session was a trial run and no actual data were collected at that time.

3.3.1 The school

Sesame Primary School was a Government school situated in an affluent Melbourne suburb. The school had 530 students enrolled with five grade six classes, four being a mixture of grade five and six student (composite 5/6) with the sixth class composed of grade six students only.

The Assistant Principal was committed to having teachers develop individualised learning plans for each student and matching the curriculum to their needs. This Assistant Principal placed a particular emphasis on challenging students rather than selecting tasks based on what students may or may not find engaging "We've moved beyond 'this is a great task, the kids will enjoy it'". The desire to challenge individual students was described as the primary reason behind structuring mathematics sessions so that students were grouped according to mathematical ability and allocated ability-appropriate tasks. All students were given access to all tasks, however, and encouraged to attempt tasks allocated to other ability groups if they wished.

3.3.2 The teacher

Elise was an experienced Primary teacher with over 20 years of service in three different Victorian Government schools. She had been teaching in Sesame Primary School for seven years and was looking forward to taking long service leave in the near future. Elise was also involved in the Australian Government Quality Teaching Project (AGQTP) at the time, in addition to taking part in the TTML project. She appeared committed to improving her teaching practice.

3.3.3 The class

Elise Heinz had a composite grade 5/6 class at Sesame Primary School. Her class had 26 students, 14 grade 5 and 12 grade 6. Of these 16 were boys and 10 girls. The class was situated in a stand alone portable that offered limited space for Elise and her students to move around. Her classroom was arranged with an electronic white board at the front and students clustered around groups of two rectangular tables joined to form squares. Displays of student work were ubiquitous along with commercial educational posters (e.g., human anatomy, maps, wildlife etc.).

For mathematics sessions Elise allocated students to one of four ability groups. Her typical mathematics lesson consisted of an introduction to the topic and then students would assemble into their groups and select tasks from those on offer for their particular ability group.

After the introduction Elise would nominate a particular group of 8-12 students to work with – usually those of lower ability – and this would become the 'teaching group' while other groups of students worked on tasks without assistance. After the teaching group was given further instruction for a period of 10-15 minutes, Elise would roam the room helping students as needed.

3.3.4 The feedback questions

Teachers were asked to formulate some questions they wished to obtain student feedback on, drawn from areas the teacher felt to be amongst their strengths and weaknesses. These and two other standard questions were then asked of students every five minutes or so during a mathematics lesson. The number of questions asked was intentionally kept small so as to minimise disruption to the lesson. Students selected responses based on a five point Likert scale.

The set of questions used in this case study were:

- How interested in this work are you right now?
- How hard are you trying right now?
- Do you agree that Ms Heinz (pseudonym) understands your learning needs right now?
- How confident do you feel about what you are doing right now?

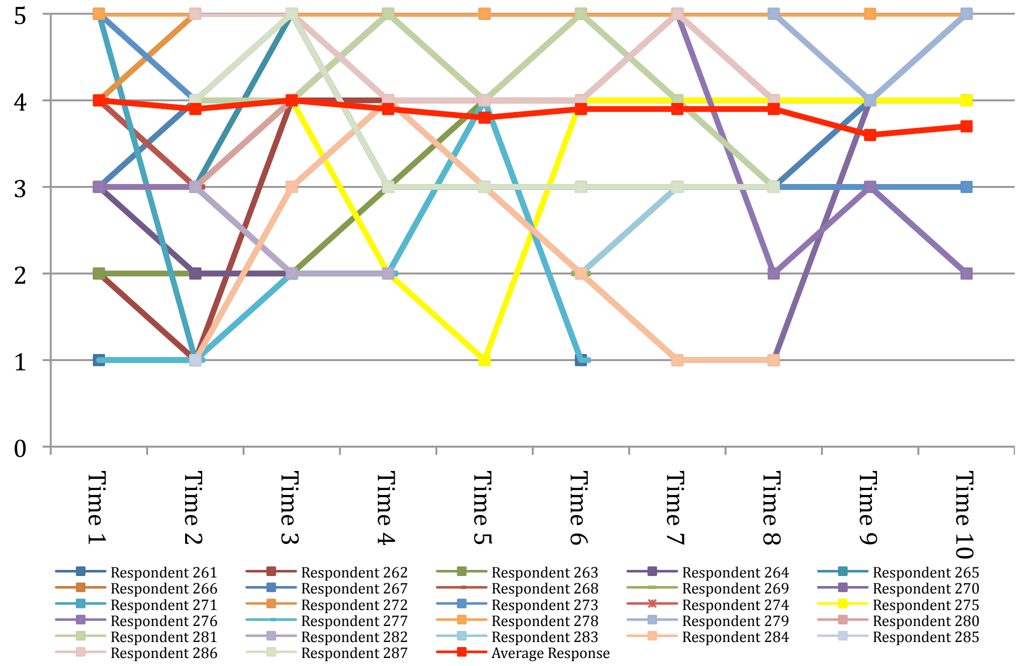
After the lesson the collected data were analysed with the teacher, followed by a short semi-structured interview to collect data on the teacher's experience of the process, their views on its utility, and any observations they cared to make on the results. The questions used to guide the interview in this session were as follows:

- What sense can you make of these results, what do you think we can conclude about your questions?
- Is there anything here which you find surprising or confusing?
- How do these responses strike you? Are there any patterns you think are meaningful?
- Is there anything that you would do differently in light of these results? What obstacles do you think you would have to overcome in making these changes?
- How useful/helpful do you think this kind of process is in terms of yours or others' professional learning?
- Could it be made more useful? How?

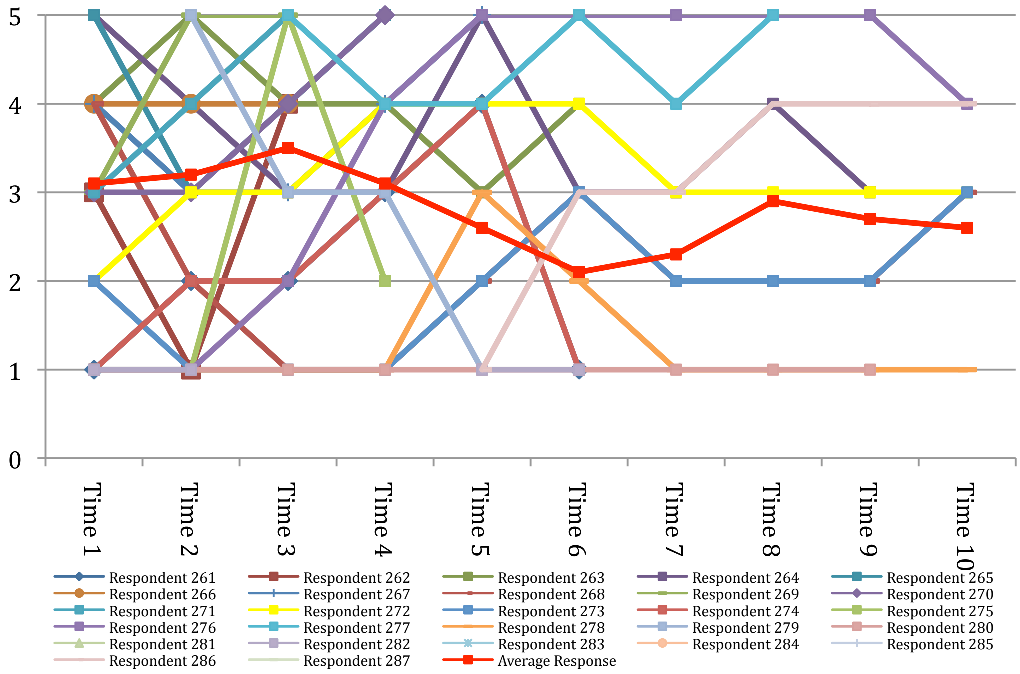
3.3.1 The results

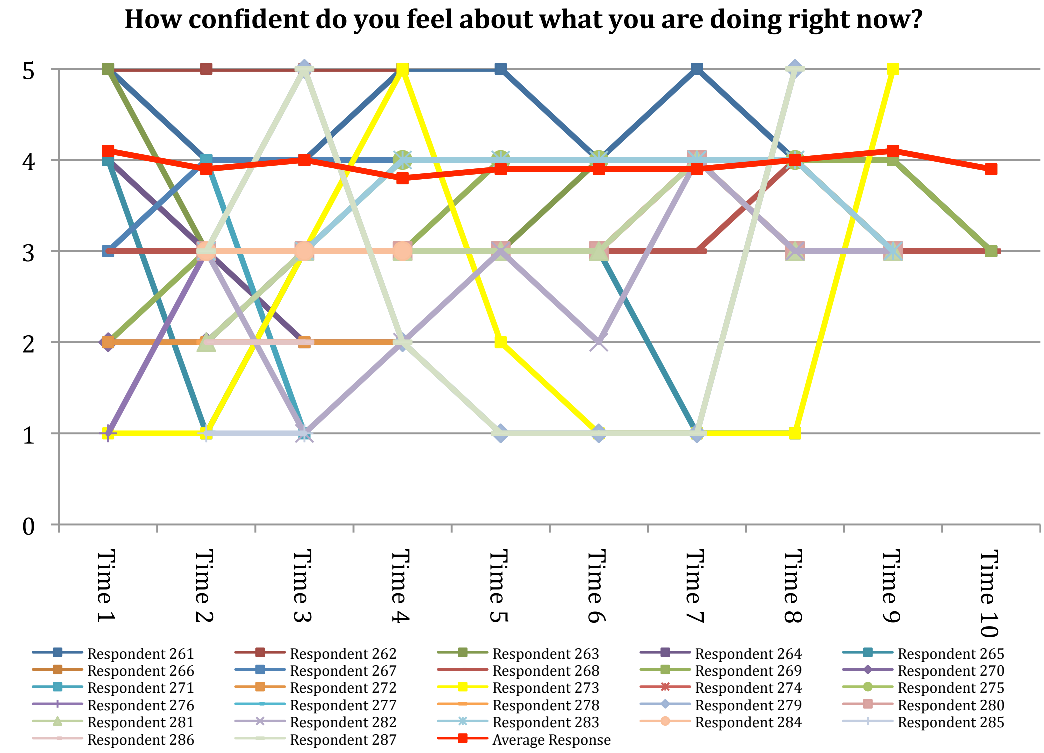
The following graphs (see Figure 3.18) were obtained from one of Elise's mathematics sessions. Each coloured line represents the feedback over time from one student, with the range of responses being from one to five on the iPod graphical Likert scales. The red line represents the average response of all students who responded within a five minute time period. This provided a visual way of capturing the average responses which were not always easy to discern due to individual lines overlapping and obscuring each other in the chart.

How interested in this work are you right now?



Do you agree Ms Heinz understands your learning needs at the moment?





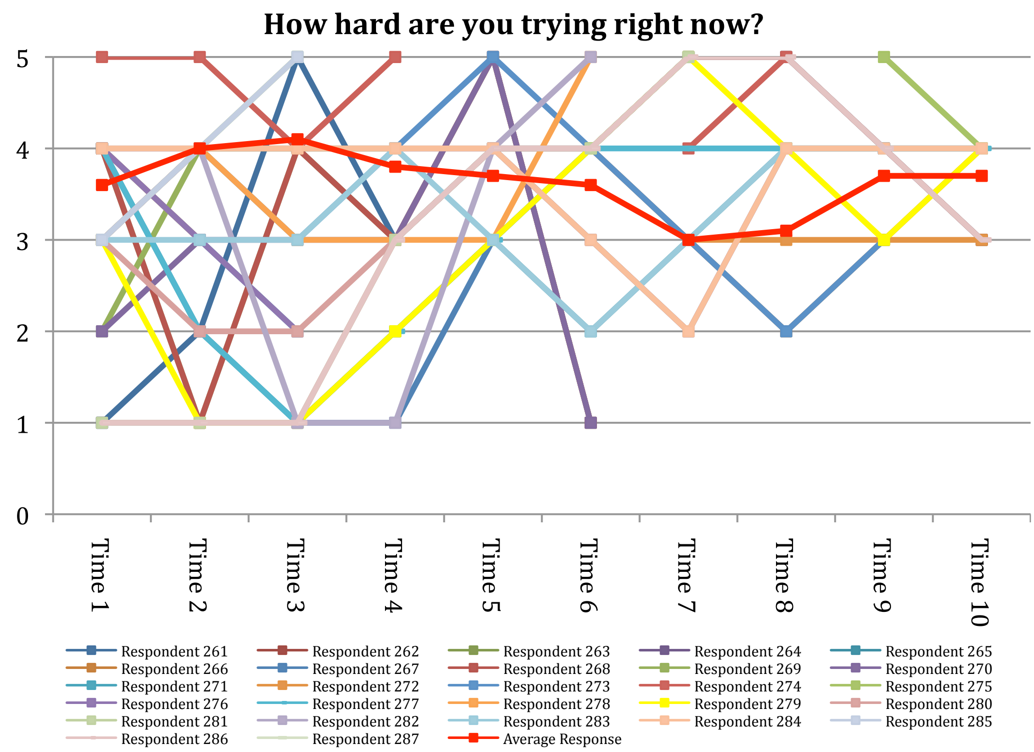


Figure 3.18 Graphical results from student feedback.

From my perspective I thought these graphs had some interesting features. First, there are relatively few flat lines which might have been generated by students tapping the same response for each questions every time they were prompted to respond. This does not eliminate the possibility that they were simply providing random responses, but at least the absence of these flat lines demonstrates that most students were not responding in a mechanical fashion. Second, on average confidence and interest levels appeared to be fairly stable throughout the lesson, while there were pronounced dips in students feeling understood and in student effort, yet for effort in particular, after Time 4 it dips below 2 only once, suggesting that while effort sagged later in the lesson, students nevertheless felt occupied to some extent most of the time, and this despite many not feeling that their needs were being well understood. More could be said about these graphs, but the real focus of the research was on how the teachers used them.

Elise chose to explore the graphs as a group of four rather than examining each one individually, and was particularly interested in responses that showed a decrease in interest, effort or confidence, and when these had occurred:

> As an average it's not too bad, they've pretty much maintained their effort across, you know, there's a couple of dips, but you know it's not sort of start up high and then gone mmmlerrrrrrr [*sound accompanied by hand gesture moving sharply down*] as the lesson's gone along, it's kind of maintained ... the yellow's interesting …
>
> The dips are interesting though, it's kind of pretty steady there then it dips and then goes back up again, I was wondering, it would be interesting if I knew exactly what time that was. And what made it go back up again?
>
> And then there's these rebel kids who stop answering half way through!

Elise appeared to accept that the graphical responses and patterns accurately reflected students' sentiments and she seemed satisfied that the tool was capturing data of relevance to her, for example she drew some comfort from the fact that interest levels did not plummet (go "mmmlerrrrrrr") as the lesson progressed. Elise also identified three students who stopped responding part way through the lesson, dubbing them "rebels". She was also keen to identify at what point in the lesson the dips in interest occurred.

In looking to explain these patterns Elise felt that it would be critical to identify not just what was happening at the time of the fluctuations, but also which line represented which student:

> I don't know what happened to the brown one, it's sort of disappeared, maybe it was Liam when he started playing with Google maps or something instead of answering questions! I think it is interesting and useful if you can correlate it to the part of your lesson you were at, because then you know oh I've bored them silly with an introduction, or they loved the hands on bit, or you know, the lesson really goes a bit too, you know 10 minutes too long.

> This brown one again, it just dies in the middle in everything! I wish we knew who that was!

Her focus on the "rebels" highlighted the need for her to be able to put names to each line of feedback. Elise felt that removing the anonymity of student responses would be crucial to making the RTFS of use to her in improving her planning and timing of activities within her lessons.

Elise's emphasis shifted from how she might use the RTFS to alter her lessons to considering how she might be able to use the RTFS as a diagnostic tool for tracking students over a longer period of time. Once again this reinforced for her the importance of linking the identity of each student to their feedback:

> If you know in your own room who each respondent is, then you can see if a child's consistently … like … they might look like they're working but they're bored silly. They're not being challenged enough or, it's too hard for them so they're disengaged, if you knew which colour was which child and you could compare it across a few weeks then you could see if they were always feeling the same way.
>
> I think if they, in two or three weeks time, if you could do, say, similar types of tasks, but you knew who the kids were, you could see if the same kids were always disengaged, or if I was going to use it as a tool I'd be wanting to do those sort of comparisons.

For Elise the RTFS offered the possibility of identifying bored students who might otherwise go undetected over a long period of time. She felt that patterns might emerge which would not only identify disengaged students generally, but identify whether students were only disengaged by particular types of task.

The disengagement theme was not Elise's only concern for her students, she was also aware of the ambiguity of the question concerning how confident students' felt with the mathematics they were working on. She also commented that high scores in the confidence question might not be an optimal result:

> That looks great at first, but then you sort of think, is that, is it too easy for them. If they're feeling really confident about it it's either that it's been explained well enough and they know what they're doing and they think 'yep I can approach this, I can have a go at it', but if it's super confident maybe it's not challenging enough, but then if it's way down then it's too hard, so maybe, you know, aiming for something about a 3 may be better with that, you don't want it to be too hard.
>
> I can look at that and say 'oh great they all feel confident!' if I don't really think about the reasons why they're feeling confident … it gives me a feeling for what they're feeling, but … not … the nitty gritty of it.

Elise was clearly moving beyond a superficial analysis of the results, delving not only into reasons that might explain the patterns, but thinking about what kind of results she would consider to be a good outcome. She also continued to identify limitations in the existing data set, sensing that there was not quite enough information for her to be able to draw any definitive conclusions.

This line of reasoning prompted Elise to consider modifying the questions she would use so as to further unravel whether her students' confidence was due to good instruction or due to a lack of challenge in the task.

> It would be interesting if there was a question like, maybe, 'how challenged do you feel by this' because then comparing that with the confidence, if it was high challenge and high confidence you'd sort of think they're still feeling challenged or ... you know they're feeling pretty good about it ... or 'does the task you're doing offer you a challenge?' something like that, because then you'd know whether they were feeling confident because … if they said it was of no challenge then you know they're confident because it's too easy.

This interrogation of the data helped to shape the way in which Elise wanted to use the RTFS in future to enable her to gain greater insight into the way her students were experiencing her lessons so that she could better extend their learning and understanding of mathematics.

Elise also requested two customised reports from her class feedback sessions that she used in her annual review the following week (see Figure 3.19 and Table 3.1).

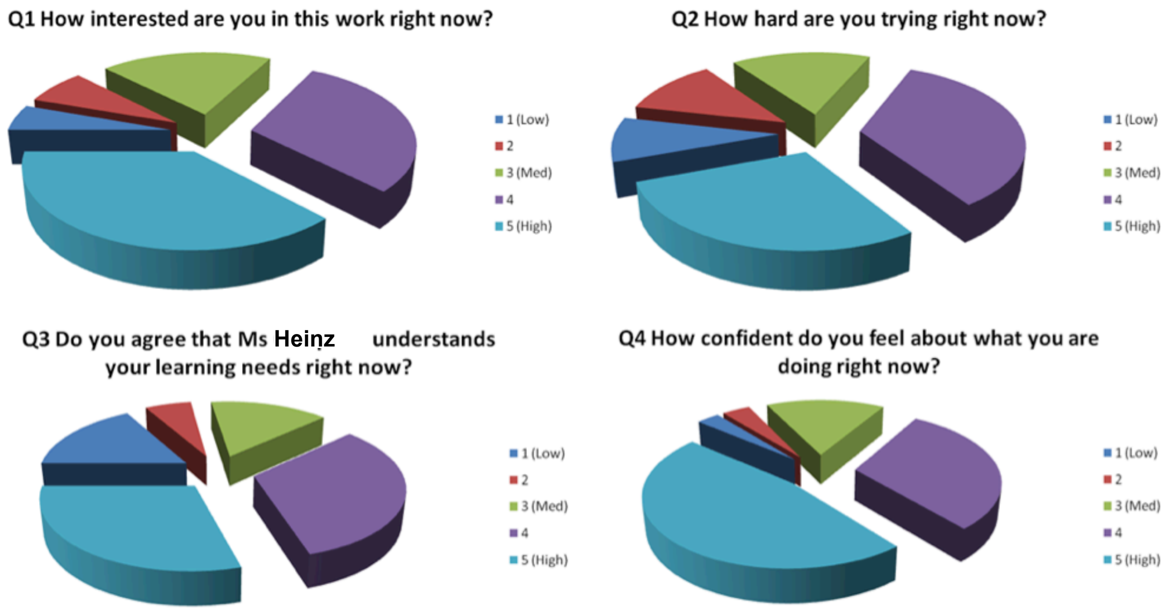


Figure 3.19 Graphical breakdown of student responses by feedback question for Elise Heinz.

These charts and table showed consolidated figures on the percentage of each response from students to each question over three lessons. She believed that these were a useful way to objectively capture some aspects of her classroom environment and to highlight the extent to which students responded positively to the stimulus questions.

There was scope to automate these outputs as part of the RTFS, in fact part of the original plan was to build up a suite of graphical displays that teachers could choose from to display their collected data. However, with the thesis taking a different direction from the original vision, this proved not to be feasible.

The follow table (Table 3.1) is a text based presentation of the same data, with the addition of an aggregated column that classifies responses into positive, neutral, or negative based on the five point Likert scale, where a response of 1 or 2 was deemed negative, 3 neutral, and 4 or 5 positive. Only the positive and negative percentages are printed. This was also produced at Elise's request as it related specifically to one of the key performance indicators that was part of her annual review relating to how her students felt about their classes.

Table 3.1 Tabulated summary of feedback for Elise Heinz.

Stimulus Question	Response	Percentage of these Responses during Sessions	Positive/Negative Responses
How interested in this work are you right now?	Not interested at all	5.3%	67.3% / 12.6%
	A little bit (2)	7.3%	
	About medium (3)	20.1%	
	Pretty interested (4)	30.0%	
	Very interested (5)	37.3%	
How hard are you trying right now?	1 (Low)	9.0%	63.2% / 20.6%
	2	11.6%	
	3 (Med)	16.3%	
	4	34.4%	
	5 (High)	28.7%	
Do you agree that Ms Campbell understands your learning needs right now?	Strongly Disagree	16.8%	61.9% / 24.8%
	Disagree (2)	6.0%	
	Neutral (3)	15.3%	
	Agree (4)	32.4%	
	Strongly Agree (5)	29.5%	
How confident do you feel about what you are doing right now?	1 (Low)	3.0%	77.6% / 6.7%
	2	3.7%	
	3 (Med)	15.7%	
	4	30.5%	
	5 (High)	47.1%	
The majority of responses are consistently positive across all questions, although negativity peaks with 'effort' and 'understanding'			

Elise asked that a short summary be provided at the bottom of the table, hence the sentence relating to overall positivity and negativity. Whilst these last two outputs from the RTFS constitute part of the results, the main reflection analysis that follows relates to the four line graphs presented earlier.

3.4 ***Reflection analysis***

One way of analysing Elise's reflections is to compare them with Van Manen's (1977) reflective categories: Technical; Deliberative; and Critical. Technical reflection relates to practical concerns focussing on "means rather than ends", Deliberative reflection contemplates the "nature and quality of educational experience", and Critical reflection addresses itself to the "worth of knowledge" itself (pp. 226-7). Van Manen (1977) proposed these categories within the context of a philosophical analysis rather than as a research tool, so a somewhat more pragmatic rendering of these categories is provided by Muir and Beswick (2007):

> Technical Description: The participant describes general accounts of classroom practice, often with a focus on technical aspects, with no consideration of the value of the experiences.
>
> Deliberate Reflection: The participant identifies 'critical incidents' and offers a rationale or explanation for the action or behaviour.
>
> Critical Reflection: The participant moves beyond identifying 'critical incidents' and providing explanations to considering others' perspectives and offering alternatives. (p.79)

By these definitions it appears that Elise's reflections progressed through all three categories. Her initial responses were quite Technical in the sense that she provided generalised observations about the overall picture of the feedback looking for obvious patterns, focussing on the dips and rises – there was no thought given to the values underlying these patterns. It is understandable that this would be the case given that it was her first encounter with the data, so looking for patterns as a first step to understand what it had to say about her lesson is to be expected.

Once Elise had gleaned the essential nature of the graphs her reflections shifted from Technical to Deliberate. At these times she was wanting to identify the points in the lesson at which the dips and rises occurred, wishing to explain the critical incidents within the lesson that may have brought these about.

However, the majority of her time was arguably spent on Critical reflection. There were several examples of this type of reflection, the first being her desire to identify individual students. If she had remained within the realm of Technical or Deliberate reflections Elise would have been quite content with depersonalised data, having little regard for the view from individual student's perspectives. Her interest in individual students extended even further with her movement beyond the obvious data patterns onto exploring of them in greater detail. For instance, Elise's rejection of the positive 'confidence' feedback demonstrated her genuine desire to challenge her students and increase their mathematical learning, rather than drawing comfort from the superficially good results. In fact Elise sought to modify the RTFS itself to help her delve further into this question, for instance one of several suggestions she had was:

> Can you have subset questions that if they did say they're feeling really confident they get asked whether it was because it was explained properly, or it's too easy, or you put me in the wrong group...

Such suggestions indicates that Elise was reflecting critically on significant aspects of her practice, including the clarity of her explanations, suitability of her task selections, and her allocation of students to appropriate groups. Elise appeared to view the RTFS as a possible source of quality information that could have practical implications for the way she structured her class and lessons.

All teachers made requests for changes to the RTFS in order to help them explore the learning of their students further. The following quotes come from these other (pseudonymous) teachers and are indicative of over forty suggested enhancements to the RTFS:

> Claire: Could we send different questions to different students? Like, even like the higher achieving kids, asking them if they're being challenged enough, and the other end asking if they're being supported enough.
>
> Andrea: I think we need to space out the questions a bit, maybe 10 minutes would probably, at least, give them a few minutes to focus back on their work and get into it - 3 to 5 minutes is too much for these kids, it's impossible for them to focus again. But it's really good for them to have distractions and work on focussing back on their work, and I think they're improving.
>
> Dan: It would be really good if we could also put in some questions on the topic instead of just straight feedback.
>
> Jane: It would be good to see a student, then the questions with the graph - one page per student, so you can see directly the question and then their graph and you can see where their interest or their effort was actually…the average line and then the individual, that would give me really useful information.

These suggestions illustrate the way in which the teachers engaged with the tool generally and that they had a sound understanding of its potential to fine tune their teaching for both *higher achieving* students and students at *the other end*, as well as recognising limitations of the system that could have negative consequences, such as it being *impossible for [students] to focus again* after too frequent prompts for feedback. Like Elise, all teachers requested identification of individual students to be incorporated into the system, showing that they all wished to be able to perform individualised analysis on their students' feedback.

Another example of Elise's consideration of her students' perspectives was when examining whether they felt she had helped them or not whilst teaching them as a group:

> Even thinking about the group I worked with, they were a really hard audience to get started on this introduction…these are kids who aren't bad at maths, but they're just sitting there looking at me saying ‘oh god, come on it's Wednesday morning, leave me alone!’ and there's just nothing coming out of them, and it could almost reflect that, but as soon as they started working on it without me, they kind of worked a bit harder, or maybe they think ‘well I'm not working I'm just sitting here listening to her’ … maybe I could try swapping maths with music …

This shows that Elise has a very reasonable expectation of her students, taking into account the need to warm students up for the day of school, and that perhaps it would be useful to resequence the day by *swapping maths with music*. Similar consideration of the student’s experiences was borne out by comments from other teachers as well:

> Andrea: I'd also be interested to see what they think about the questions I'm asking them, and how helpful the parent helper is…
>
> Dan: What you're looking at [graphs of student feedback] is useful because you could… well, see, kids don't always tell you, and you don't always ask! But over time you could work out which are the kinds of lessons which kids are enjoying the most and which they are getting the most out of.
>
> Jane: I'll show the kids these, because I love to share this stuff with the kids, and they'll know if that is them or not. If you had it all the time, and used it once a week or which particular lessons this could give some really useful information and help me to really work out what works and what doesn’t for the kids.

As with Elise, these comments display a warmth and for their students, with them *loving to share this stuff with the kids,* wanting the students to share *what they think about the questions* they’re being asked*,* and wanting to find out what they *are enjoying the most.* Beyond simple positive regard for their students, these teachers also want to find out how best to help them succeed by knowing *how helpful the parent helper is*, what the students are *getting the most out of*, and *what works and doesn’t work* for them.

Elise was aware that the dips in reported effort may have been due to them being slow to warm to the task, or that perhaps her students do not feel that they are working hard during periods of direct instruction. Both are potentially valuable insights for Elise, each of which could impact on her teaching. If students are slow to warm to mathematics in the morning, she could change her schedule and spend the time more profitably on more creative or artistic subjects. Alternatively if it is just that students do not feel like they are making an effort during her explicit teaching she might minimise the time spent talking to a group and/or make them more interactive.

Overall Elise and the other teachers seemed to have engaged in fruitful reflection on their mathematics lessons, spending relatively little time in technical reflection and a considerable amount of time in critical reflection. They were interested in utilising the RTFS to both improve their practice and structure their classroom in ways that would most benefit their students. The next step was for them to incorporate the RTFS into their practice.

3.4.1 Teachers using the RTFS on their own

Ultimately the RTFS was designed to be a tool for teachers to use in their own classrooms. To these ends one teacher agreed to trial the system on her own over a three week period. Several sessions were conducted with her to ensure that both she and her class were familiar with the technology. My telephone and email contact details were provided in the event of any technical hiccups or to provide any other technical support during the trial. I purposefully chose not to initiate any contact during this period to ensure that the teacher was not feeling any additional pressure to use the equipment, so as to approximate real conditions as much as possible.

During the three week period the teacher did not initiate any contact either, and on the Tuesday at the end of the time when I returned to pick up the system and discuss the process with the teacher I found that she had left on long service leave the previous Friday, and the equipment had essentially not been touched.

Disappointing though this was, I made arrangements with another teacher to conduct a trial over another three week period. I went through a similar familiarisation process as before, but this time set up the questions and groups with the teacher so that no further interaction beyond starting and stopping the system was required for them to use it. After the first week I emailed the teacher to see how he was getting on, but did not receive a reply. After a further week I contacted him again and he explained that the chargers did not seem to be working properly, so he had not been able to use the iPod’s yet. I offered to come out and look at what was going on, but he assured me that he had found and rectified the problem himself – the wrong extension lead had been plugged into the wall socket. After the third week when I went back to the school the teacher had limited time available to discuss the use of the equipment due to yard duty and afterschool meetings. He also indicated that the charging issue had not been fully resolved afterall and so he “didn’t get around” to using them “very much”. There was no evidence in the database of the system having been used at all.

A third teacher agreed to trial the tool for a two week period, but a combination of sports days, school camps, and concert rehearsals ended up not making it feasible for her to use it “properly”, and on the one occasion when it was used the school had a lock down drill that resulted in the equipment being put away soon after having been handed out.

3.5 *Some reflections on teacher reflection and these results*

Critical reflection, or its equivalent, has been put forward as a vital part of teacher learning for nearly a century (Day, 1993; Dewey, 1933; Martinez & Mackay, 2002; Schön, 1983; Zeichner & Lister, 1996). Many definitions of critical reflection emphasise its role as a process of self-development, political action, and social reform, all of which appear to fall well beyond the ken of a typical classroom. For instance Day (1993) argues that we need to “ensure that the reflective process really can lead to empowerment so that the micro-political world of the classroom is seen within the social-political world of the school and the broader macro-political world of society” (p. 90). Similarly Valli (1997) describes critical reflection as “the only form of reflection that explicitly views the school and school knowledge as political constructions” (p. 78). And Van Manen (1977) suggests that critical reflection “implies a commitment to an unlimited inquiry, a constant critique, and a fundamental self-criticism” (p. 221).

Not only does critical reflection carry these weighty responsibilities but it is also described as having a personally transformative or quasi-spiritual dimension. For example Tremmel (1993) describes reflection in terms of Zen Buddhism mindfulness and that “Zen, which is not totally dissimilar to Schön’s approach to reflection-in-action, helps us transcend to that wider range of practice” (p. 443). Zeichner and Liston (1996) explain that reflective teaching “can be an intensely personal and challenging endeavour” (p. 19) and advocate a collegiate, collaborative and cooperative environment similar to Palmer’s (2004) mutually transformative ‘circles of trust’.

Viewed from these transformational perspectives, much if not all of Elise’s reflections are reduced to being merely technical in nature. For instance, Valli

(1997) described technical reflection as when "teachers judge their own teaching performance on the basis of externally imposed criteria" (p. 75). Since the assistant principal had articulated the central role she believed challenging students plays in being a good teacher, Elise's concern with challenging her students is arguably no more than an attempt to enact the desires of her school's administration – or at least using this as the yardstick by which to measure her own efforts. This was particularly evident in Elise's use of the RTFS data to help in her annual review. Two other teachers used the same reports as part of their Victorian Institute of Teaching re-registration process.

However, this would be a harsh reading of these teachers' reflections. It is much fairer to say that they were striving to improve their own technique and classrooms for the benefit of their students, rather than seeking to perpetuate a power relationship that subjugates students. They very much had their students' interests at the fore of their thinking and reflecting, whilst seeking to preserve their own careers at the same time. These need not be mutually exclusive concepts in an environment where improved teaching is valued.

The transformational idealism inherent in some of the reflection literature seems to place an almost super-human responsibility on teachers. Unsurprisingly this is somewhat reminiscent of the high expectations many women place on themselves when having children for the first time to be perfect mothers. Placing such high expectations on oneself can be a highly counterproductive exercise. It is perhaps instructive to consider Winnicott's (1958) notion of the *good-enough mother* as a parallel here. In his analysis of mothering the perfect mother who immediately satisfies every need of their child is both unrealistic, unsustainable, and ultimately unhelpful to the development of the child. Instead he advocated the good-enough mother who is able to tend to most of the needs of the child as they arise, but not always completely, and not always in a timely way. For Winnicott (1958) this helps preserve the mothers' sanity whilst simultaneously promoting the child's development for coping in a potentially hostile world rather than preparing them for life in a non-existent paradise where every whim is catered for.

Thus in a parallel way it may be better to conceive of a *good-enough teacher* as being something to which teachers can realistically aspire to, and actually attain, rather than promoting perfect, critically reflective teachers who seek to transform the world with every lesson.

Desforges and Cockburn (1987) highlighted the contract that exists between teachers and students which is almost the antithesis of reflective teaching since, as Sullivan and Leder (1992) noted, "students' actions and responses in the classroom are important determinants of the way teachers teach" (p. 625). As a result, students, parents, and schools themselves can actively resist the efforts of a perfect teacher who wishes to bring about transformative practice. If students react in an adverse way to the efforts of a transformative teacher then little transformation will occur, and the teacher's energy and time will be consumed by dealing with an unruly class. Similarly, if the school administration, colleagues, and/or parents, resist such efforts, the teacher is likely to feel isolated, undermined, and wholly unsuccessful.

It is important for educational researchers to understand the real world implications of any postulated ideals, and the negative impact such idealism can have on teachers' confidence and professional sense of self. The point is poignantly made by Desforges and Cockburn (1987) in quoting a teacher who had attended a professional development session; "I don't know why I keep going to meetings to learn more about becoming a better teacher. I already know how to teach ten times better than I ever can" (p. 12).

3.6 *Conclusions*

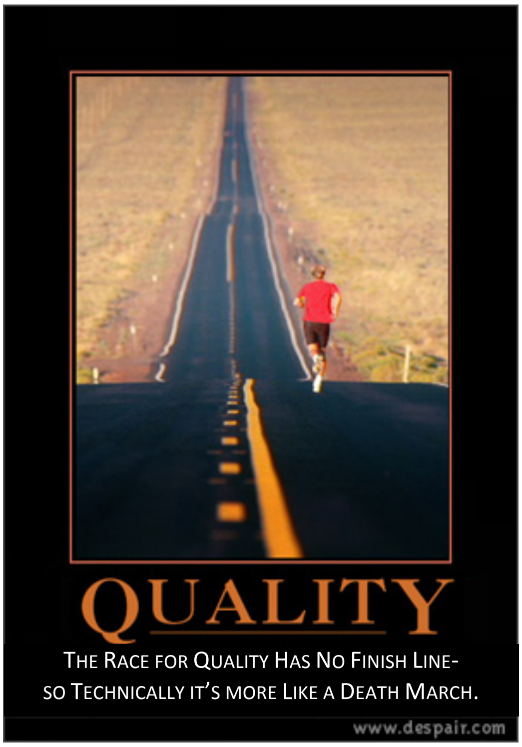
The RTFS appears to have been effective in prompting teachers to engage in data driven reflection on their teaching. The extracts presented in this case study demonstrate that teachers were rapidly drawn into critical reflection, using Muir and Beswick's (2007) definition, in their seeking to understand the graphical representations of their students' feedback and, in turn, develop insights into the perspectives of these students. This process seems to have enabled them to consider what this feedback might mean for their own practice, and how they might adopt alternative strategies to enhance their students' learning. Furthermore, all teachers proposed improvements to the RTFS to make it a more useful tool for them in future data collection and reflection, which serves to demonstrate the critical nature of their reflections in terms of obtaining the best outcomes for their students. The fact that their efforts may be likely to be judged harshly in terms of the reflection literature is perhaps more of an indictment of the inherent idealism of that literature than of the pedagogical thoughts of these teachers.

It was clear, however, that when left to their own devices teachers struggled to use the RTFS by themselves. This suggests that either the technical difficulties associated with new technology (e.g., charging the iPods, interacting with the setup screen, navigating the graphical results etc.) were difficult for teachers to overcome, or that the teachers had no real interest in using the RTFS (despite statements to the contrary), or that the classroom has so many other competing pressures that there was simply no room for additional lower priority demands to be met.

Whether one or more of these possibilities accurately reflect reality, the fact remains that the RTFS proved unsuitable to being used by teachers for their own purposes without assistance. Recently the DEECD employed Teacher Coaches who provide intermittent assistance to mathematics teachers across a number of Government schools. It may be that the RTFS is ideally suited to this kind of support for teachers rather than having to manage the tool themselves, however, at the time when I was trialling the RTFS there were no Teacher Coaches so it was envisaged that teachers would take responsibility for its use. This is evidence of a gap between my own expectations as a researcher and the practical realities of the mathematics classroom. The realisation of this gap in my own thinking, coupled with the apparent gap between the reflection literature idealism and teachers' realities started to draw my attention to other gaps that seemed to exist between mathematics education research and mathematics classrooms. Some of these are explored further in the next chapter.

CHAPTER 4

Expectations and observations in research



4.1 *A different road*

This chapter marks the departure point from the original intentions of this research. It continues from the issues raised in Chapter 3 around placing unrealistic expectations on teachers, as evidenced by my own assumptions given the unsuitability of the RTFS to be incorporated into the practice of teachers who had used it. It further explores issues relating to idealism within educational research, some of the implications of these for teachers, and how this may be linked to mathematics culture.

Some of the philosophical aspects surrounding classroom observations are investigated and there is a short report of findings from the first teacher survey (Appendix I) relating to ambitious teachers being more willing to allow their classrooms to be observed than less ambitious teachers. This starts a theme developed further in Chapters 7 and 8 relating to who makes educational decisions relating to mathematics, and how their personal traits and experiences may have an adverse influence on school mathematics education.

4.1.1 Unreasonable expectations

Without having fully realised it, the notion of idealism within educational research had been a growing concern for me as I took part in other aspects of the TTML project. One of those activities involved classroom observations and teacher interviews with visiting international scholars. The issue came to the fore for me when the visitors were very critical of the lessons of one of the more experienced and engaging teacher participants. This teacher's efforts were criticised for not making the most of the learning opportunities that presented in the lesson, for not 'nailing' the mathematical concepts. It was this stark criticism that brought to my consciousness for the first time the difficulties teachers face in living up to the expectations of educational researchers. It occurred to me that regardless of how skilled a teacher was, they would always be subject to criticism for not meeting one or other set of criteria of which they were oblivious – something like the 'death march to quality' depicted at the start of this chapter.

It seemed to me that what constituted a good teacher lay entirely in the eyes of the beholder and the theoretical framework to which they subscribed. This was the nascent beginnings of what later became clearer to me from the analysis of teacher reflections outlined in Chapter 3 as the prevalence of idealism in education research. This is explored below in the context of 'nailing' lessons, as well as investigating the idea of the *good-enough teacher* in terms of data captured on teachers' work patterns and how they judge their own performance.

4.1.2 Teachers 'nailing' lessons

Observations of lessons by visiting scholars and by members of the research team often noted that teachers did not quite 'nail' the lesson, that is, teachers did not drive home the key mathematical learnings of the task in hand. This failure appeared to occur for a variety of reasons, including teachers' lack of content knowledge relating to the focus of the task; teachers misjudging what the key point of the task was; teachers being distracted from the key focus of the lesson; or teachers running out of time for a variety of reasons such as interruptions, equipment failure, activities taking longer than anticipated and so on.

In the lesson alluded to above the teacher had posed the task: "the perimeter of a rectangle is 20 cm. What might be the area?" The class worked productively on the task, with most students working with a partner. It would not have been obvious to the teacher but some students were calculating the area of their rectangles by counting, rather than by multiplying, and it was this aspect that the observers took exception to. While it does expose a weakness in the task, in that the numbers involved were too small to prompt multiplication as efficient strategy, it is hardly grounds for criticism of the teacher, particularly given that many of the students using a counting strategy were intentionally discrete and hid their counting from the teacher.

Despite the use of a rubric (see Appendix III) to help structure observations, it was nevertheless the case that judgments about the success or otherwise of a lesson were largely subjective. Several of the sessions which were not nailed were arguably successful in other ways, however nailing the lesson was given priority as one major area of concern when judging lessons.

From a methodological perspective there are important assumptions built into the notion of judging whether a lesson has been nailed or not, and it would seem that there are three possible scenarios;

i) Teachers don't nail lessons (Observers are correct)

ii) Observers don't nail observation (Teachers do nail lessons)

iii) Teachers don't nail lessons and Observers don't nail observation

Each of these will be considered further below.

4.1.2.1 Teacher don't nail lessons

There are several reasons why i) could be correct and that teachers don't nail lessons:

- Teachers may try to nail lessons but are incompetent;
- Teachers may not actually try to nail lessons;
- Teachers may try to nail lessons, and may be competent at doing so, but nailing lessons may be very difficult or impossible in reality; or,

- Teachers may try to nail lessons, and even be competent at doing so, but nailing the lesson may sometimes/often/always be a lower priority than other goals or constraints teachers have or face during the lesson.

4.1.2.2 Observers don't nail observation

A similar list exists for ii):

- Observers may be incompetent at observing;
- Observers may not actually try to nail observations (of course this raises the question of 'then why bother observing?', although there may be other psychological or political factors involved);
- Accurate observation may be very difficult/impossible to achieve in reality;
- Observers may try to nail observation, but doing so becomes a lower priority than other factors that arise during the session.

4.1.2.3 Teachers don't nail lessons and observers don't nail observations

The third option seems to be the most likely of the three, that neither teachers nor observers entirely nail their respective tasks. It seems reasonable to expect teachers to be constrained in their ability to focus on each mathematical nuance or, in some cases, significant mathematical point, to the same extent that a passive observer can imagine them to be capable of doing. Armchair coaches are notoriously adept at imagining that players can do more than they are actually able to do. By the same token, it seems reasonable to expect that observers are limited in what they can actually experience in any given lesson, and may miss or overlook aspects of a session that might have changed their impressions/expectations. It is also possible that since teachers are more familiar with the intended audience of their lesson (the students), that teachers are better judges of what to emphasise and when to emphasise it than the observers are. This suggests that observing lessons is neither a simple nor neutral task. In some ways it could be said that an attentive observer is observing themselves to the extent that the things they see are those of particular interest to them, while other events of minimal interest are missed or ignored. This also implies that the teacher comes to the classroom with a particular set of interests, and the extent to which they overlap with the observer's set of interests may determine the light in which the lesson is seen. A closely related concept is Kuhn's (1962) description of observations as being theory-laden, in that observations are influenced by whatever theory they relate to. The next section explores this issue further.

4.1.3 The theory-laden nature of observation

Classroom observers coming to a classroom interested in particular things and missing or underemphasising others is symptomatic of a broader, and more radical, problem with observation. Kuhn (1962) pointed out that all observations are theory-laden. That is, what a person sees is partially determined by the worldview or paradigm they embrace. Kuhn's (1962) famous example is that of the duck/rabbit gestalt figure (see Figure 4.1 below). If the observer is familiar with ducks, then they are likely to see a duck, if familiar with rabbits then they will probably see a rabbit. If the observer is unfamiliar with such representations of either animal then they may see a squiggly line and a dot, or a map of a harbour, or something else entirely. But each distinct experience arises from the same set of markings on the page, and no one interpretation can claim priority without further information or justification.

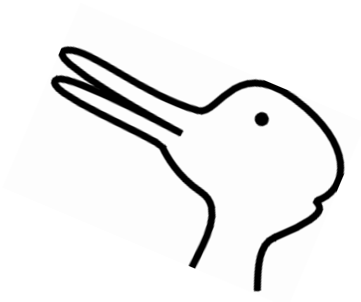


Figure 4.1 Kuhn's (1962, p.111) visual duck/rabbit analogy for theory-ladeness.

Theory-ladeness represents a form of bias that goes beyond an observers' preferences because it influences the way they perceive the world in the first place, and therefore help to shape their preferences and biases. In the case of mathematics educational researchers, arguably their primary focus is on the transmission of mathematics. For the mathematics teacher, particularly in primary schools, their primary focus is typically elsewhere, usually the students that they have been teaching all year. It is perhaps unsurprising, then, that observers and teachers focus on different things during mathematics sessions and come away with different experiences – one has been plausibly looking at ducks, while the other at rabbits.

There is, of course, a considerable overlap between the concerns of the observers and the teachers in this case. The observers hope to improve the way teachers generally can teach mathematics to students, and teachers often hope to be able to glean insights gained by such research. However, the theory-laden nature of observation led Kuhn (1962) to further argue that competing explanations or theories of phenomena are, in fact, incommensurable. For instance, within Newtonian physics the mass of a projectile remains constant (assuming no other influences), whilst within Einsteinian physics the mass of an object changes with velocity. Whilst the two theories seem to share considerable common ground, even the same words for similar concepts, they are nevertheless speaking about completely different things. Even though it is possible to argue that Newton's physics is a special case of Einstein's, it is not possible to translate Newtonian physics incrementally into Einsteinian physics, rather the conceptual framework, or paradigm, needs to be replaced in its entirety.

The implications of the incommensurability of theories for scientific realism, naïve and otherwise, were profound – after Kuhn it was no longer tenable to assume the neutrality of observations, observational language, nor epistemic frameworks for preferring one theory over another. And this was within sciences dealing with 'objective' external realities. The problems of neutrality within social and human research are exponentially greater still.

A clear example of this is provided by Sullivan, Mousley, and Gervasoni (2000) who provided a means of assessing the issue of classroom observation directly. In their study 22 teacher educators provided written responses to a videotaped lesson complete with pre/post interviews of the teacher. In analysing the responses the authors were struck by the disparity, and the quite individualistic (almost personal) basis of the critiques proffered, despite all observers having viewed the same material.

The question, then, of whether teachers really do or do not nail lessons remains open. As argued above, it is likely that they do not, at least not in the way observers anticipate, but they may well nail them in other ways that satisfy other criteria that feature more highly on their priorities, such as spending more time with a particular student, managing behaviour, or dealing with the latest interruption. In any case, the notion of objectively nailing a lesson remains problematic because of the inherent theoretical structures underpinning those making such judgments.

4.1.4 Does it matter if teachers don't nail lessons?

Putting to one side the issue of whether we can ever know if a teacher nails a mathematics lesson or not, and assuming for arguments sake that we can know, it still remains to establish whether it actually matters if lessons are nailed or not. Is student learning contingent on lessons being nailed? If the lack of lesson nailing is as widespread as seems to have been the case in TTML observations, then there is a serious question of how students learn mathematics at all. There is, of course, data to suggest that students are not learning mathematics as well as they might, which may, in part, be due to this phenomenon (Department of Education, Employment and Workplace Relations, 2008). However, there are clearly students who are learning mathematics well, perhaps in spite of a lack of lessons being nailed. If it is possible for these students to develop thorough understandings of mathematical concepts in the face of poor teaching, then there must be other mechanisms at work.

It may be the case that these students benefit from the particular style of the teacher, or that the teacher focuses their energy on those whom they believe show promise or need the most help. Or it may relate to student motivation, access to resources beyond the classroom such as a helpful parent, sibling or friend, or an innate talent that blossoms despite a less than conducive environment.

One of the TTML teachers, Lloyd, went to great pains to provide as much scaffolding and support as was needed to assist students in grasping the mathematics being taught. Lloyd would routinely spend 30 minutes or more working with a group of four or five students during mathematics sessions. He was extremely patient and persistent in identifying misunderstandings these students had developed. He would consistently listen to students, challenge them, and tease out generalisations and formulations. However on these occasions the rest of the class was essentially left to their own devices, and whilst there was no evidence of disruptive behaviour, most of the groups were observed to be simply chatting socially rather than engaging in any of the mathematics tasks they had been asked to tackle. So while Lloyd may have been able to nail certain concepts for some students, the others were left to their own devices. It would be interesting to investigate whether such intensive bursts of attention are better at developing mathematical understanding than more traditional methods, however, even in the small group working with Lloyd it was often observed that one or more of the group were disengaged unless being spoken to directly.

It would be unreasonable to conclude that nailing mathematics lessons is essential to students learning mathematics, however it would seem reasonable to speak of nailing lessons as a more efficient means of teaching mathematics. The readiness of students to understand and embrace a new mathematical concept is inevitably as diverse as the students themselves. This entails that some students may well grasp the concepts even though the teacher has failed to nail the salient points. By the same token, nailing those points may only be sufficient to increase the understanding of a percentage, even majority, of students. The remaining students are likely to need even more assistance than nailing the lesson would provide. Tzur (2008) provides an example of a motivated and competent teacher who seems to have felt that he had nailed a lesson only to find that few of the students had made the connections he had hoped for. So whether a lesson is nailed or not may be in the eye of the beholder, or more correctly, the learner – and some students may learn when a lesson *is not* nailed, and others may *not* learn when a lesson *is* nailed.

4.1.5 Implications for the teaching profession

If many teachers are unable to nail lessons, for whatever reasons, *and* nailing lessons is crucial to student learning, then it would seem that students are being actively disadvantaged by having teachers who cannot nail lessons. In such a situation it would be vitally important to identify the reasons behind such pedagogical failings and seek to rectify them. If it is due to incompetence, then seemingly a large part of the teaching profession would need to be re-educated. If teachers are not attempting to nail lessons then it is important to understand why, and to better understand what exactly they are attempting to do with their lessons, however, this seems the least plausible explanation.

It seems more plausible that teachers do attempt to nail lessons but have different priorities, or perhaps that they do not attempt to nail lessons *because* they have different priorities. The subtle difference here is teachers' intentions. In the case where teachers are attempting to nail their lessons it would appear that their intent is frequently foiled, whereas in the latter scenario, where nailing lessons has a lower priority, then any nailing would be accidental, either coincidental to achieving other priorities, or a by-product of achieving those other priorities.

It is important to be clear about the competing expectations placed on teachers, especially as they come under greater scrutiny from the community. The Victorian Minister for Education recently stated teachers were naïve to oppose the publishing of data about their performance, "you…can know more about the performance of your air-conditioner than the progress of your local school" (Tomazin, 2009). It remains unclear what impact such an approach will have on teachers nailing lessons or not, but it potentially assists in prioritising teachers' efforts. There have been a number of claims of cheating by teachers and principals attempting to skew the results of recent National Assessment Program – Literacy and Numeracy (NAPLAN) testing (Chilcott, 2010b), while reports of widespread 'teaching to the test' have also been made (Chilcott, 2010a). For educators to respond in this way represents somewhat of an antithesis to nailing lessons in that rather than encouraging students to develop detailed mathematical understandings they are instead seeking to maximise their performance on standardised tests.

This serves to underscore the competing pressures mathematics teachers face that complicate both their work and the work of those wishing to observe and understand what is going on in classrooms. It helps to support the view that out of the three possibilities above, it is the third that is most likely to be the case: that is, neither do teachers nail their lessons, nor do observers nail their observations. This leaves open the question of which phenomenon is dominant, and which is occurring in any given instance – it is quite possible that a teacher nails a lesson but the observer misses it, or even a situation akin to Tzur (2008) where both teacher and observer believe the lesson was nailed, but the students remain unchanged by the experience.

4.1.6 The prevalence of 'right ways' in mathematics

The notion of nailing lessons may stem from a common attitude in mathematics of there being a right way to do things. It could be said that such an attitude forms part of the dominant paradigm within mathematics generally. It is interesting to note another of Kuhn's (1962) observations that what distinguishes science from non-science is the dominant paradigm that occupies the thoughts and efforts of practitioners during Normal Science phases. The received view of the dominant paradigm permeates the efforts of all research centres and there are accepted 'truths' that all embrace to a large extent. By contrast, humanities and other non-scientific areas of endeavour have no such guiding paradigm – everything is up for debate, and divergent views abound with little or no common ground. Interestingly, for Kuhn (1962) the teaching of science is instrumental in bringing about the success of science since students are only exposed to the research success stories, as if science were a harmonious monolithic process moving smoothly from one breakthrough to another – none of the historical squabbles or cul de sacs are emphasised. Science is portrayed as a unified field of knowledge gradually uncovering truths through the scientific method, whereas the humanities emphasise personal opinions and views, and often rake over the coals of historical disputes.

Mathematics is an important adjunct to this process. In many ways it represents an even 'purer' form of truth in the sense that mathematical objects reside in human consciousness as abstractions that correlate with the outside world. Two plus two really does equal four by definition, and no measurements or other physical means are required to test this. A necessary corollary of this is that mathematical problems have right and wrong answers. It is commonly believed that there is no ambiguity in mathematics, you either get the right answer or you do not. This is one of the oft cited reason many people enjoy mathematics (Solomon, 2009).

Getting the right answer seems to be intimately bound to the field of mathematics, and to the *mythos*, or unstated worldview, underpinning mathematics. Students who consistently fail to get the right answers may quickly feel isolated from a potent part of society, while those who are proficient at mathematics can experience a form of social isolation from the majority and feel rejected and labelled as 'nerds' or 'geeks'. Socially speaking it seems better to be neither a 'vegie' nor a 'geek', rather it seems that being 'ok' at maths is the most socially acceptable option.

This attitude seems to spill over into the teaching of mathematics. Teachers can become concerned with whether they are 'doing it right'. All of those who used the RTFS were interested in knowing how the responses of their students compared, broadly, with the 'normal' responses;

> Elise: Is that what the others got?
>
> Dan: How does that compare with, you know, like the feedback other teachers get?

It is plausible that anxiety about whether they were doing the right thing or not motivated, at least in part, the majority of TTML teachers to opt out of classroom observations – a point to be explored further shortly. Arguably mathematics education researchers seem to also view teachers in the light of whether they are 'doing it right' from their own particular perspective. For instance, in the study mentioned previously, Sullivan et al. (2000) report that one of the criticisms raised by a scholar critiquing the video taped lesson was "why (choose a) capitalist model instead of a government funded hostel, hospital, school etc.?" (p.258). This was a more clear example of ideologically driven comment, but there were others – particularly with regard to the ceding of control to students rather than the teacher being particularly directive. Indeed, one of their conclusions of the study is that the academics all responded in terms of rights and wrongs rather than recognising that there is a spectrum of approaches where teachers might position themselves.

This suggests that some mathematics education researchers do consider there are right and wrong ways of teaching, and perhaps helps to explain why teachers are reluctant to be observed and judged. Teachers cope as best they can under the circumstances, including their workplace, their student cohort, the classes they are allocated, their own personality and mental health at any given time. Everyone has good and bad days and it is well known that a lesson that worked well for one class may not work anywhere near as well for another – with or without the same teacher. This demonstrates the level to which personal ideology impinges upon observation, the theory laden nature of the exercise, and the range of topics over which teachers' actions can be found wanting. This level of pushing one's own perspective is perhaps a necessary part of research into Mathematics Education as evidenced by the considerable variety schools of thought within the field. The difficulty comes when teachers are expected to satisfy any number of criteria that they are largely oblivious to.

Even when most observers might agree on what is an appropriate response to a situation, it remains a uniquely subjective process. Bishop (1976) demonstrated, there are an infinite number of responses to any given situation that a teacher might pursue. For example, the following diagram (Figure 4.2) illustrates a variety of possible responses to a hypothetical situation involving subtraction:

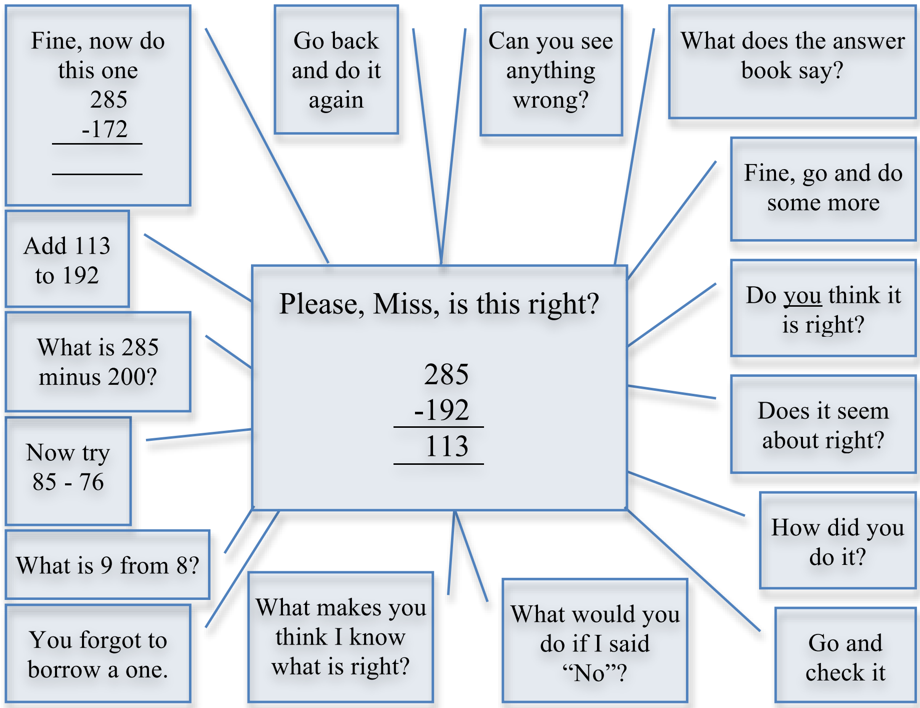


Figure 4.2 Bishop's (1976, p.42) hypothetical decision making situation.

Clearly there are many possible responses to such a scenario, of which these might be considered typical. However, each teacher will likely have their own preferred approach to dealing with such situations well rehearsed. In fact Bishop (1976) claims that experienced teachers do, or they may respond in more spontaneous ways. There could be many justifications given for any choice, and many other justifications for why the approach selected was inferior. Beauty remains in the eye of the beholder. However, it is clear that not all choices are equal. Corporal punishment is obviously unacceptable as a response to a child who asks for assistance. But such a response is already illegal. Giving the student a detention would appear unreasonable, but in some circumstances this might be appropriate – perhaps if the question is asked repeatedly in the middle of a test. The point here is that any given response could have a context invented to make it sound reasonable – even extreme responses. It depends on the circumstances.

It seems reasonable to assume that Mathematics Educational Research looks to provide answers to 'typical' classroom circumstances where the desire is to enhance childrens' understanding of mathematics. However, this decontextualised advice must be operationalised by those who are immersed in context, namely the teachers and students. Observers of these interactions are unlikely to be fully aware of the underlying context and focus instead on the more abstracted elements of the interactions such as the content of the lesson and the mathematical concepts. This necessarily excludes a great deal of what is actually going on in the classroom. By contrast, the very thing that the observers/researchers are not privy to, the relationships and contextual content, is what constrains teachers in their ‘delivery’ of the abstracted content, bringing about the situation described by Sullivan and Leder (1992) wherein students have significant influence on their teachers.

Such a view is also compatible with Leatham’s (2006) notion of teachers as having sensible rather than contradictory belief systems. The relationships and context of the classroom that can make sense of teachers’ decisions are not typically available to observers, and teachers may not be conscious/feel comfortable/feel able to adequately explain the underlying issues. The politics of the classroom involve complicated relationships between teachers, students, parents, families, administrators, and others which defy simplistic analyses. Thus the idea of judging whether teachers are ‘doing the right thing’ or whether they are good enough remains fraught with difficulty, especially when viewed from a narrow theoretical perspective.

This again illustrates the emic/etic distinction and the difference between high ground and swamp perspectives. It also demonstrates a possible source of disconnection between the foci of researchers and practitioners within a culture steeped in notions of right and wrong techniques. It is perhaps not surprising, then, that most teachers preferred not to participate in classroom observations, as will be seen in the following section.

4.2 *Participant willingness to be observed*

Methodologically it is significant that some teachers are willing to be observed while others are not since this can be a source of bias in collected data. Some data were collected with the TTML participants which speak to this point, and the following section briefly explores some of these findings. While this short section appears to deviate from the thrust of the argument being developed, it is included here as a precursor to a theme expanded on in Chapters 7 and 8 relating to who makes educational decisions and what biases effect these decisions.

Setting to one side the philosophical difficulties underlying classroom observation, there were survey data collected from the TTML cohort at the commencement of the project relating to teachers' willingness to be observed, and around their career intentions (see Appendix I). Analysis of these results yielded a connection between a willingness to have classroom observers and high career aspirations. It is interesting to note that those most willing to be observed tended to be those, arguably, most keen to be promoted out of the classroom. This could pose a problem for observations in terms of a skewed population, but also coheres with the observations of Connelly and Clandinin (1995) that many teachers experience, and prefer, teaching to be a solitary, private activity between themselves and their students.

4.2.1 Teachers' willingness to be observed

As discussed previously, the TTML project involved many classroom observation sessions, often including visiting scholars. Observations typically consisted of three parts: a pre-session interview with the teacher to identify their pedagogical intentions; the actual observations of the session by one or more researcher using an observation rubric (see Appendix III) as a data collection guide; and a post-session interview to capture the teacher's impression of how the session went, to explore any issues that arose, and to identify any aspects of the session that surprised the teacher.

Not all of the participating teachers expressed a willingness to be observed – of the original 61 teachers surveyed (see Appendix I), 56% expressed a willingness to be interviewed, while only 38% were willing to participate in observations. This illustrates the point that only some teachers are prepared to be observed by researchers, and may be evidence of teacher discomfort at having strangers judge their practice along the lines of Connelly and Clandinin's (1995) notion of the teaching landscape being immersed in moral admonitions. On the other hand it might simply indicate a level of apathy amongst teachers.

4.2.2 Results of initial teacher survey for un/willing observees

The different level of willingness to be interviewed compared to willingness to be observed suggests that there is something other than apathy motivating the responses. If teachers were merely apathetic toward the project they would most likely seek the path of minimal contact with researchers and, as a group, be as unwilling to be interviewed as they were to be observed. In fact observation probably intrudes less on their time and requires less active involvement than being interviewed, so apathy might be reasonably expected to yield at least as many, if not more teachers willing to be observed than interviewed.

Given the responses received, it seems plausible that there were two reasonably discrete populations of teachers that were likely to share other attitudes besides an unwillingness to be observed teaching. In order to test this hypothesis t-tests were performed against both groups (willing or unwilling to be observed) for their responses to other surveyed variables likely to be relevant. Since the willing to be observed group only had 20 members, two tailed t-tests were the most appropriate way to establish any statistically significant differences based on the groups' responses to Age, Sex, Number of Years Teaching Mathematics, Level of Mathematics Education Attained, Current Employment Status, Effort put into Annual Reviews, Interest in Seeking Promotion, Intention to Remain a Classroom Teacher, and Sense of being Valued by the Principal, Colleagues, and Students.

Interestingly there were no discernible differences for the majority of these variables and only two showed a statistically significant difference in responses between those willing to be observed and those unwilling to be observed. The two variables were Interest in Seeking Promotion, and Intention to Remain a Classroom Teacher. The questions from the initial teacher survey were as follows:

17. How interested are you in pursuing promotion or positions of responsibility/leadership?

0	1	2	3	4	5	6	7	8	9	10
Totally Disinterested										Extremely Interested

20. How long would you like to remain a classroom teacher?

0	1	2	3	4	5	6	7	8	9	10
I Want to Get Out Now!!										The Rest of my Working Life

For Question 17 the mean responses of all teachers (n=61) was 5.2 with a standard deviation of 3.12, while for Question 20 the mean response was 6.9 with standard deviation of 2.58. The results of the t-tests for each of these responses based upon the categories of willing or unwilling to participate in classroom observation yielded the following:

```
Promotion/ObsYes         Promotion/ObsNo
N:      20               N:     41
Mean:  7.3               Mean:  5.0
F:     1.18
t:     2.9               p(same):     0.004

Keep_Teaching/ObsYes     Keep_Teaching/ObsNo
N:      20               N:     41
Mean:  5.9               Mean:  7.4
F:      1.04
t:     -2.07             p(same):     0.043
```

Figure 4.3 t-test results for those willing and unwilling to be observed based on Questions 17 and 20 of initial teacher survey.

These results suggest that we can be very confident ($p<0.01$) that there is a genuine underlying difference in attitude toward seeking promotion between those who were willing and those who were unwilling to have observers in their classroom. We can also be confident ($p<0.05$) that there is an underlying difference in attitude toward how much longer these groups of teachers plan to remain in the classroom. In particular, those willing to be observed reported significantly higher ambitions than those unwilling to be observed, and they also reported intentions to leave classroom teaching significantly sooner than those unwilling to be observed. So it could be said of those willing to be observed that they are more ambitious and more likely to leave teaching sooner than their colleagues who were unwilling to be observed.

The original intention in posing Question 20 was to help identify teachers within the cohort who were likely to be uninterested or less motivated than others because of career plans beyond education. It seemed reasonable to expect teachers who do not have long-term plans to remain in the classroom to be considering departure from the profession entirely. The surprising result here is that these teachers may not plan on remaining in the classroom for other reasons than a desire to leave education, but rather because they are interested in pursuing leadership positions within schools that would take them out of the classroom.

However, further analysis suggests this may not be the case either. If it is the case that those seeking to leave the classroom earlier wish to do so because of promotional aspirations, then a further t-test based on groupings around responses to question 20 (how long would you like to remain a classroom teacher) should yield similar results to those noted above – namely that all aspirant teachers are more inclined toward leaving the classroom sooner than later. However, forming two sub-groups from all of the teachers based on whether their response to Question 20 was between 0 and 5, or 6 and 10 and performing a t-test between these two sub-groups based upon their desire for promotion yielded no significant differences:

Promotion/KeepTchg0-5		**Promotion/KeepTchg6-10**	
N:	19	N:	42
Mean:	6.42	Mean:	5.41
F:	1.185		
t:	1.184	p(same):	0.260

Figure 4.4 t-test results for those wishing to pursue promotion (Question 17 of initial teacher survey) based on categorisation of duration of remaining a classroom teacher (Question 20).

This suggests that while on average teachers who intend to leave teaching sooner are slightly more ambitious than their colleagues who intend to stay in teaching longer ($\bar{x}$=6.4 versus $\bar{x}$=5.4), this is not statistically significant (p=0.26). This could be accounted for by the choice of cut off point used to distinguish between those who intend to leave soon and those who do not and this may warrant further investigation. In any case, this result does not contradict the earlier finding of those willing to be observed being more ambitious and intending to leave teaching sooner than those who did not wish to be observed.

4.2.3 Elaboration of these results

The fact that the previously detected pattern is not replicated across the entire cohort of teachers suggests that willingness to take part in classroom observation is an important factor in the observed differences in responses, it is not just a matter of ambition alone. There are several possible explanations for this. It could be argued that those who are particularly interested in pursuing promotion are willing to be observed because they see it as an opportunity to further their ambition in some way: perhaps being seen as complying with the administration's wishes; being perceived as confident and/or competent; believing there may be positive reports back to the administration; or that they are keen to obtain feedback from the researchers to help improve their teaching.

While participation in observations might be seen as a mechanism to realise their ambitions, it could also be argued that these teachers were willing to participate because they are confident of their teaching skills, and therefore confident of their suitability for promotion. Their plans to leave the classroom in the near future term (relative to those teachers unwilling to host observers) may be indicative of a self imposed deadline for promotion after which they may well consider leaving education entirely. Alternatively they may be planning to leave the classroom soon because they expect their ambitions to bear fruit in the near term, thereby removing them from the classroom.

It would be somewhat ironic if those most willing to fully engage in professional development projects, such as TTML, are the very teachers most likely to leave the classroom soonest. Lacey (2004) found that many teachers felt that anyone unwilling to embrace externally driven performance targets were passed over for promotion. One of the more common external performance measures being used with teachers now is student performance on National Assessment Program – Literacy and Numeracy (NAPLAN) test results. So while it is possible that the ambitious TTML teachers are seeking out every opportunity to further enhance their pedagogical skills via being observed, it also seems likely that this is driven by a desire to further their careers and move into positions of leadership.

Gronn and Lacey (2005) report that leadership aspirants who feel unsupported by their principals or colleagues pursue alternative career paths. There is no evidence here that these teachers feel unsupported by either their principals or colleagues, in fact the average responses for the observed group are both fairly high, with a slightly higher sense of being valued by their colleagues ($\bar{x}$=8.0) than principals ($\bar{x}$ =7.5). Those unwilling to be observed had a similar response pattern with an average of 8.1 for feeling valued by colleagues compared to an average of 7.1 for feeling valued by their principals. However the observee's shorter timeline for departing the classroom is suggestive of a "succeed or leave" attitude.

4.3 *Some conclusions about observations and expectations*

It seems that classroom observations are fraught with difficulties in terms of making judgements of how successful teachers were in any given lesson and whether they 'nailed it' or not. The theory laden nature of observation entails that each observer sees different things, especially when their views are informed by different theoretical constructs and are not privy to the complexities of the relationships that exist within the classroom under observation. This can lead to ideologically driven judgements that devalue the teachers' efforts.

Additionally, the cohort of teachers willing to be observed appears to be a discrete subset of all teachers in that those teachers who are most ambitious are also the most willing to expose themselves to expert scrutiny, while those with minimal career aspirations prefer to opt out of being observed. Also it is those who intend to leave the classroom soonest that are most likely to embrace classroom observations, while those who intend to remain as long term classroom teachers opt out. It could be that aspirational teachers are willing to 'burn brightly' for a shorter period of time, embracing change and critiques, whereas longer term teachers prefer to consolidate their own practice gradually. This unwillingness to be observed suggests that many teachers do not wish to obtain feedback from academics, or perhaps do not value their feedback. Yet, the TTML project was apparently relevant to the participating teachers, connected directly to their classroom practice, and overall seemed to be well received. It was conducted by sensitive researchers who were respected in their field and who had productive things to offer these teachers, yet few were willing to be involved in observations. This suggests that practitioner/academic divide definitely exists, and is consistent with the negative views many teachers seem to have of pre-service teacher education (Zumwalt & Craig, 2008).

Further evidence of this divide is perhaps encapsulated in the way that some teachers do not appear to satisfy the ideals of the reflection literature, and others failed to satisfy the expectations of academics wanting them to nail their mathematics lessons – even though the impact of nailing lessons on student learning remains a somewhat open question. It seems clear that teachers can be seen to fall short of any number of educational ideals. It is possible that these idealistic expectations are symptomatic of a broader practitioner/academic divide, or they may arise from the mathematics education culture itself, in which certain techniques become the right way to do things. Either way it underscores the contested nature of whether we need perfect teachers or good-enough teachers.

Given the problematic nature of stimulated reflection and teacher observations, it occurred to me that it would be useful to enquire of teachers how much they work, how they know whether they are doing a good job or not, and whether they feel competent or not in order to investigate how realistic it is to expect more of teachers. The next chapter explores these questions further.

CHAPTER 5

Teachers' Sense of Success

5.1 *Introduction*

It is suggested in the previous chapter that a gap exists between mathematics education researchers' expectations of how mathematics teachers could or should approach their teaching and what teachers actually do. More than this, it is suggested that this gap is insurmountable due to the gap between academic idealism and pedagogic pragmatism. Unlike physical sciences where investigations are conducted within the bounds of widely accepted paradigms, much educational research arises from far more individualistic theoretical frameworks which often do not cohere with each other. In the absence of a clear, unifying world view on education, teachers will potentially always be found to fall short when judged against any number of competing theoretical perspectives. In Kuhn's (1962) terms mathematics education research could be described as being in a pre-paradigmatic, or pre-scientific, phase.

For a teacher seeking guidance on how to improve their practice, such diversity of opinion can prove to be unhelpful, hence Desforges' and Cockburn's (1987) teacher who already knew how to teach ten times better than s/he ever could. This lack of practicality potentially alienates teachers from the very community seeking to assist them to improve their teaching. Because of this perceived gap it was important to investigate how teachers judge their own performance, and to find out more about their work patterns. This was achieved by administering a short Teacher Work survey (see Appendix III) to the TTML participants.

5.2 *How teachers judge their own performance*

5.2.1 Teacher self assessment

The Teacher Work survey consisted of eight questions, three relating to work hours, three open response items relating to judging teaching performance, and two Likert scale items asking teacher to rate themselves as teachers. The survey was administered at one of the final TTML teacher meetings and in total there were 18 respondents, all Primary teachers, all of whom had been involved with the TTML project for nearly three years.

In order to try and capture some of data about teachers' sense of how they knew if they were doing a good a job, the fourth question on the Teacher Work survey asked precisely that:

4. How do you know if you are doing a good job?

The responses were free form and therefore quite diverse. These were categorised based upon the responses received, using a *grounded theory* approach that allowed the categories to arise organically from the data rather than attempting to fit them into any preconceived theory. It is acknowledged that such categorisation cannot be done in a purely neutral manner, however the intention was to identify a small number of broad themes that could give some structure to the various responses.

Grouping the 88 responses resulted in identifying 25 distinct criteria that teachers used to assess their own performance. These criteria were then further condensed into four broader categories: Student reactions; Professional judgement; Personal judgement; and, External sources. Examples of the criteria that were grouped into these categories are provided in Table 5.1 below.

Table 5.1 Examples of responses to Question 4 of the Teacher Work survey: How do you know if you are doing a good job?

Response Category	Number of Criteria of this type	Number of Responses of this type	Examples of Responses
Student reactions	13	49	Students are excited to be at school
			Feedback from students
			Students are motivated to learn (and so on)
Professional judgement	4	4	I am basing my teaching on research
			I am organised
			I am aware of students' needs and abilities
			Self reflection on my work
Personal judgement	3	3	I enjoy/still have a passion for teaching
			I feel sane
			Based on my personal sense of things
External sources	5	31	Annual review with principal
			Parent feedback
			Feedback from colleagues
			Successful outcomes for students on NAPLAN
			Employability

Although the second and third categories accounted for over a quarter (28%) of the distinct criteria offered by teachers, they only accounted for 9% of actual responses (see Figure 5.1).

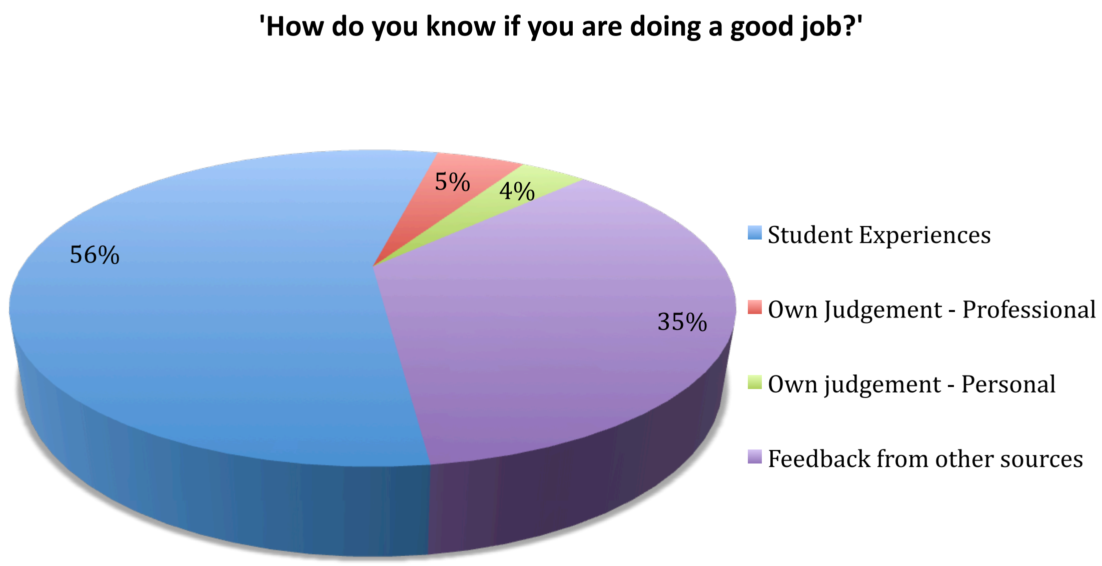


Figure 5.1 Pie chart of categorised teacher responses to Question 4 of the Teacher Work survey.

These criteria collected from teachers were not intended to be exhaustive, but indicative of the kinds of things teachers used to judge their own performance. While the proportions depicted in Figure 5.1 may not be a reliable indicator of the weightings teachers give to such criteria, it does help to illustrate the areas considered most significant.

All teachers (n=18) provided between two and eight responses ($\bar{x}$ = 4.9) as measures of their own performance. As can be seen in the pie chart, over half of the criteria teachers use to gauge the quality of their work related to their observation and judgement of student reactions, while over one third related to feedback from parents, colleagues, principals or standardised testing. In rough terms these teachers indicated that in judging their own performance they rely on the reactions of others (students and external input) and their own judgement in a ratio of around 9:1. That is, their personal and professional judgements of how well they are teaching is almost insignificant compared to the reactions of students and others in the school community. This reinforces the considerable impact that student reactions seem to have on teachers (Sullivan & Leder, 1992), which gives some insight into what they consider to be important, and provides a stark contrast with the emphasis on idealism evident in some educational research.

Question five on the Teacher Work survey asks about the role of professional development (PD) in helping them to determine how good a job they have been doing as teachers:

5. Has there been any PD or other sources that have helped you to know how good a job you are doing? If so, in what ways?

Two thirds of the respondents either explicitly stated that there had been no PD that helped them in this regard, or only mentioned ‘other sources’ such as the items covered in category iv) in Question 4 (i.e., feedback from colleagues, parents, principals etc.). The remaining third commented that the only PD external to the school they had found useful in judging how good a job they were doing was that which involved discussion of good practices that they could identify within their own teaching. Only one respondent directly nominated their participation in the TTML project as being helpful, although this was not strictly an aim of the TTML project, and the broader description of ‘good practice’ would include projects such as TTML in any case. All teachers provided between one and four responses ($\bar{x}$ = 2.0).

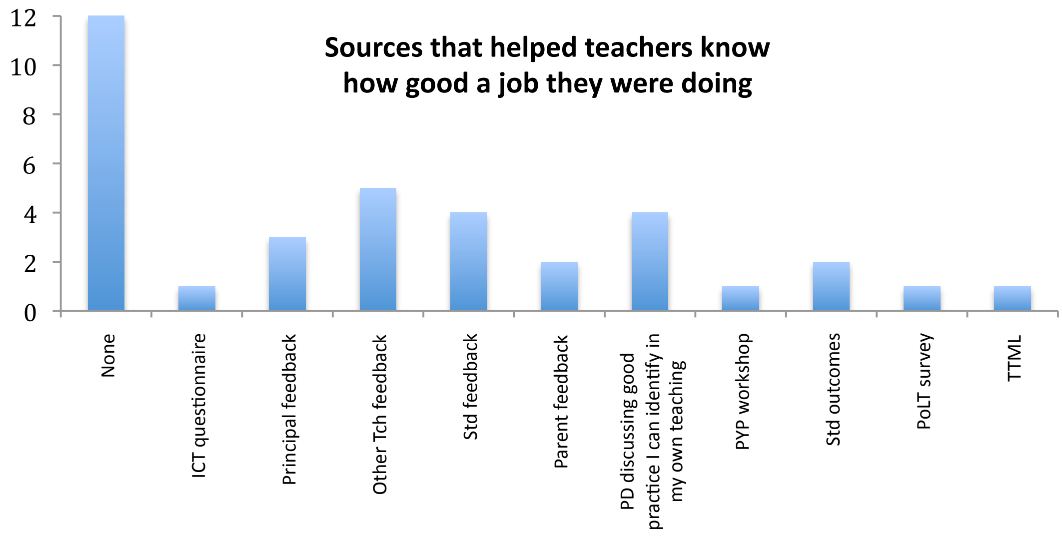


Figure 5.2 Teacher responses to Question 5 of the Teacher Work survey.

This highlights a potential disconnect between professional development and practising teachers in terms of providing guidance on how well they are performing as teachers. It again highlights the importance to teachers of feedback from students and other school community members.

The third question posed regarding quality of teaching in the Teacher Work survey was as follows:

6. What kind of things do you think makes someone a good teacher?

This evoked quite a different set of responses from Question 4 (how teachers knew if they were doing a good job). While Question 4 generated only 9% of responses that related to the professional skills or personal qualities of the teacher, 100% of responses to Question 6 were categorized into one of these two categories. All teachers provided between two and seven responses ($\bar{x}$ = 5.1) for what they thought made someone a good teacher. In total 92 responses were collected across 37 discrete categories. All 37 categories could readily be further categorised into either professional skills, or personal qualities. Examples of responses are provided in Table 5.2 below.

Table 5.2 Examples of responses to Question 5 of the Teacher Work survey: What makes someone a good teacher?

Response Category	Number of Criteria of this type	Number of Responses of this type	Examples of Responses	
Professional skills	15	36	Caters to individual abilities and learning styles	Create opportunities for creativity and choices
			Prepares students to become life-long learners	Knowledge of subject matter
			Effective communicator	Being organised
			Sound understanding of current pedagogy	Builds life strategies
			Professional environment	Make work interesting, challenging, and fun
			Reflective	Active learner willing to use what they learn
			Share ideas	Prepared to be challenged
			Work in a team	
Personal skills	22	56	Compassionate	Like kids
			Caring	Passion for teaching
			Patience	Approachable
			Caters for whole child not just in class	Good listener
			Sense of humour	Develop positive relationships with students
			Humility	Willingness to work with kids at lunch and after school
			Openness	Hard work
			Understands individual students personally	

As can be seen in Figure 5.3 the majority of items nominated related to personal qualities (such as patience, sense of humour, caring), with 39% pertaining to professional skills (such as being organised, effective communicator, sound understanding of current pedagogy).

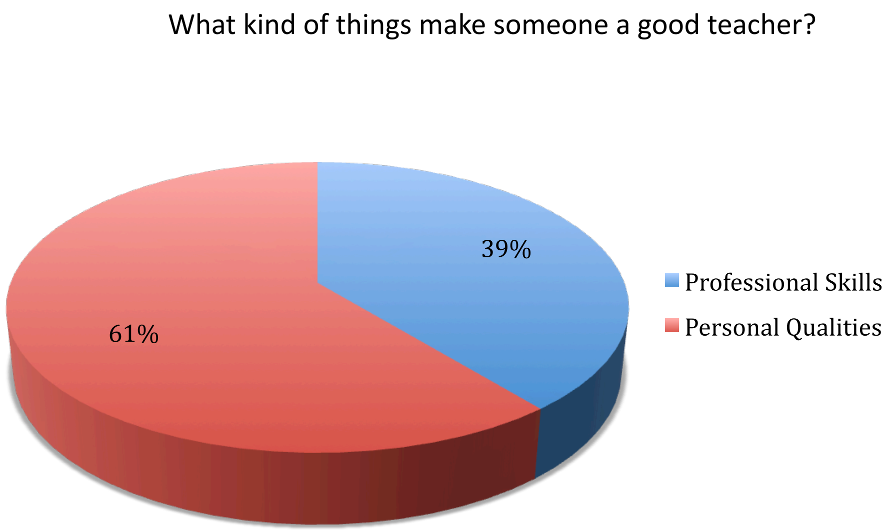


Figure 5.3 Chart of categorised responses to Question 6 of Teacher Work survey.

This emphasis of teachers on personal skills and qualities over professional skills further illustrates the student-centric, relational aspects of what teachers see as constituting being a good teacher. Some of the professional skills are also concerned more with individual or collegiate relationships (sharing ideas, work in a team) than abstract teaching skills (prepares students to be life-long learners, knowledge of subject matter). Arguably these skills are more like personal qualities of teachers than being particular skills of the teaching profession *per se*. If counted in this way the percentage of personal factors would rise to 79% and professional skills would sink to only 21% of total responses.

5.2.2 Implications of these results

The main inference from the above responses is that teachers do not seem to be getting a clear message from professional development activities of how effective they are in their teaching, and are instead relying on processes predominantly within their school, and mostly within their own classroom. This potentially reinforces the idealism/pragmatism divide between providers of professional development and those seeking to improve their practice. It may be the case that teachers do not relate professional development to their own practice, or that professional development is not covering material that teachers find useful in gaining insight into their own practice. These are not mutually exclusive possibilities, but if the former is true then it becomes irrelevant if the latter is true.

That is, if teachers do not identify anything of value within the professional development on offer, it does not matter whether those delivering the training have attempted to make the material relevant or not because, from the teachers' perspective, it is not relevant. This would represent a further gap between the designers and recipients of PD, since if professional development offers materials and approaches that teachers can use to improve their practice (ostensibly the entire purpose of PD), then it would all be for nought if teachers do not make the necessary links back to their practice. Conversely if teachers are able and willing to make such a link but the PD does not provide anything useful, then we are back to teachers having to rely on their own sources of information, as indicated in the survey responses.

It may be the case that teachers are willing and able to make such links, and that professional development provides a rich array of materials and techniques for teachers to draw on, but that the nett results of this process are swamped by the overwhelming demands of the dominant sources indicated by the survey results. That is, the impact of feedback from parents and students vastly outweighs any feedback and reflective opportunities inherent in any professional development experience.

There are at least three possible implications:

i) Teachers do not draw the link between PD and their practice;

ii) PD does not cover material relevant for teachers to link to their practice;

iii) Other feedback mechanisms outweigh PD generated reflective feedback.

Each of these is considered further below.

5.2.2.1 Teachers do not draw the link between PD and their practice

If teachers do not connect their professional development experiences to their teaching practice then it casts doubt over the efficacy of most, if not all, professional development. If teachers are unable to make the link between what is presented as best practice or ways to improve and their practice, then it negates the value of professional development at the outset. It is not entirely unreasonable that teachers might not connect PD to their practice since it is relatively rare for teachers to observe other teachers in action, and hardly ever to observe themselves in action. The act of teaching is very different to observing and analysing someone else who is teaching: this is the familiar emic/etic distinction.

However, this is unlikely to be the case since a number of respondents explicitly stated that they found PD useful that involved discussions of good practices that they could identify within their own teaching. Additionally, the manner in which teachers engaged with the Real Time Feedback System suggests a willingness to incorporate new information into their practice, that is, they were open to modifying their pedagogy based on relevant information. So it seems that connecting relevant PD to their own practice is probably not the biggest obstacle to teachers benefitting from PD.

5.2.2.2 PD does not cover material relevant for teachers to link to their practice

In this scenario the difficulty lies almost exclusively with the designers of professional development. Given teachers have shown a willingness to make links back to, and modify their practice, it seems that they may have found little to inspire changes from the professional development experiences they have had. If this is the case, then there is an urgent need to explore different ways of designing and delivering PD. In many ways this was much of the purpose of the TTML project, seeking to provide a long term, explicitly classroom relevant, community building approach to teacher professional development. The fact that it did not feature prominently in teachers' feedback suggests that either they did not perceive it to be PD in the 'typical' sense (i.e., a short workshop as part of a conference, staff meeting, or curriculum day), or that the other factors raised are so dominant that they overwhelmingly determine the ways in which teachers think about their practice.

5.2.2.3 Other feedback mechanisms outweigh PD generated reflective feedback

Given the prevalence of non-PD related responses to how teachers know how good a job they are doing, it seems that these factors are uppermost in teachers minds. This may simply reflect the fact that teachers spend only a tiny fraction of their work life undertaking external profession development, which might underscore the limited value external professional development may have in terms of influencing teachers' practices. This possibility is consistent with two observations from this research. First, as mentioned above, the fact that the TTML project was not widely identified as a source of gauging how good a job they were doing suggests that even an ongoing multi-year professional development project has a minimal impact on how teachers think about the success of their teaching. Second, the fact that none of those participants who took part in trialling the RTFS actually used the system on their own, despite the enthusiasm shown in interviews, suggests that teachers' time and energy is fully consumed by what is already occurring in their classrooms and schools. The kinds of pressures teachers are under is captured in a short quote from an interview with a teacher who was explaining why she struggled with implementing open ended mathematics tasks:

> I felt some of the kids were floundering and they just got fed up and couldn't be bothered with it, so I think you either have to be really good at knowing when to step in with those kids and give them the right sort of prompt. But you've also got to make sure that you're available to do that in the context of the classroom activity because sometimes you're busy with someone who needs help and then someone else needs a different type of help, and you can't be everywhere at once prompting the kids as they need it.

This captures both the kinds of immediate demands that teachers face coupled to the relationships they need to form with their students, *knowing when to step in* with the students who struggled whilst simultaneously catering to the needs of the other students.

Whether these difficulties represent something that would taper off with experience and familiarity with open ended questions or not is not clear. However, it does demonstrate that there may be a significant threshold that teachers and students need to overcome in trying something new for it to be successful. It may be that greater work needs to be done on transitioning teachers from current practices into new ones in order to make the change a smooth and rewarding experience rather than a trial by fire.

Few would argue that teaching is not a difficult business, yet much of mathematics education research focuses on how teachers can, or need to, do a better job. As Bishop (1998) has pointed out, research in mathematics education largely identifies perceived problems in the field and creates pressure for change without providing any real guidance for what change should occur. There seems to be a paucity of research outlining at what point a teacher can claim to be doing a good enough job already. Bishop and Nickson (1983) poignantly summarise this situation as follows:

> There is no doubt that to be a member of the mathematical community and to bring a full range of professional skills to the teaching of the subject must pose a considerable demand upon any mathematics teacher. It is difficult to assess the realism of such a demand, but it argues strongly that more individual guidance needs to be given in the professional development undertaken by mathematics teachers. (p.56).

This speaks to the lack of clarity over what constitutes a good-enough teacher given the call for "more individual guidance" for teachers, and perhaps captures some of the essence of the practitioner/academic divide alluded to in the previous chapter. It also raises the question of how realistic it is to demand more of teachers, and is suggestive of the emic/etic distinction being embodied in the fact that mathematics education researchers focus on mathematics as their primary concern, while teachers focus on students as theirs.

It is also perhaps striking that neither the Victorian Institute of Teaching (the accrediting body for Victorian teachers), the Department of Education and Early Childhood Development (DEECD – the major Victorian Government department responsible for Government schools), the Catholic Education Office (the central administrative office of the Victorian Catholic school system), nor the Australian Education Union (the major public sector teacher union in Australia) were mentioned by teachers as sources of professional benchmarks. Presumably such organisations have pedagogical excellence firmly as their core business. It is true that Victorian Government schools are tasked by DEECD to monitor annual progress of teachers, and several teachers did nominate their annual reviews and principal feedback amongst the criteria they use to judge their teaching.

However, whilst Government schools advocate benchmarks as part of their workforce plans, there is no guarantee that these benchmarks are useful and/or meaningful. For instance Figure 5.4 shows the review document used with all teachers in a large Government secondary school from 2008 – 2010. In this document teachers were expected to "continually update", "continually develop", and "continually broaden" their knowledge, understanding, skills etc. It is difficult to take such claims literally, or in some cases even seriously. The rhetorical nature of such expectations is further underscored by the tick box format of the document. The bottom section asking teachers to indicate that they have met the standards is more suggestive of a statutory declaration of proficiency rather than signing off on a performance review that might have otherwise involved the production of evidence of performance, or at least discussion around salient points. Presumably those teachers who nominated their annual reviews as having provided useful feedback went through a somewhat different process.

	KNOWLEDGE				PRACTICE		ENGAGEMENT	
STANDARDS	1	2	3	4	5	6	7	8
	Teachers know how students learn and how to teach them effectively.	**Teachers know the content they teach.**	**Teachers know their students.**	**Teachers plan and assess for effective learning**	**Teachers create and maintain safe and challenging learning environments.**	**Teachers use a range of teaching practices and resources to engage students in effective learning.**	**Teachers reflect on, evaluate and improve their professional knowledge and practice.**	**Teachers are active members of their profession.**
TEACHERS AS PRACTITIONERS OR EDUCATIONAL LEADERS IN SCHOOLS...								
CHARACTERITICS OF PRACTICE	I continually update my knowledge of learning and research into teaching and learning to support my own practice and/or the development of effective practice for others in the profession.	I continually update and deepen my understanding of the content they teach and/or support others within the profession to do so	I continually develop and/or gather and use a range of information about the learning of students and factors that influence their learning, to support effective learning programs.	I continually develop my knowledge of students, content and pedagogy to establish clear and achievable learning goals for students and/or work with others in the profession to build effective learning programs.	I continually develop my understanding of practices, strategies and resources that create a safe and stimulating environment for learning.	I continually develop my understanding and skills to manage, support and/or promote a range of teaching and learning practices that result in effective student and/or teacher learning.	I regularly reflect on, seek feedback and critically evaluate their professional knowledge and the effectiveness of their practice.	I contribute to the development of school communities that support the learning and well being of both students and fellow staff.
	Criteria met:	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*
	I continually update my knowledge of teaching practices to engage students in effective learning and/or assist others in the profession to do so.	I am conversant with current curriculum policies, programs related to the content they teach and/or their implementation in schools.	I communicate with students and their families to support learning and build productive partnerships and/ or support others to do so.	I plan for and/or use a range of activities, resources and materials to provide learning for all students	I continually update and develop my capacity to build and/or support others to develop learning environments that engage and challenge students and encourage them to take responsibility for their own learning.	I continually broaden my under-standing of teaching and learning strategies, technologies and resources that they use and/or use to support the practice of others.	I work collaboratively with other members of the profession to share practice and engage in discussion of contemporary issues and research to improve professional practice.	I promote learning, the value of education and the profession of teaching in the wider community.
	Criteria met:	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*	*Criteria met:*
	**** Criteria met – please tick the check boxes for each characteristic listed above***							
	I______________________ agree that I have met the STANDARDS as outlined in the SAMPLE CHARACTERISTICS OF PRACTICE (*Criteria met* checkboxes above) and that I am meeting the requirements specified within the Performance and Professional Development plan for 2008.							
	Signed off by...	**Name:**		**Role:**	**Signature:**			**Date:**

Figure 5.4 Teacher performance review document used at a Government secondary school.

5.3 *Relating professional skills to mathematics teaching*

The Teacher Work survey also asked teachers to rate themselves as mathematics teachers.

8. How good a maths teacher do you believe you are?

0	1	2	3	4	5	6	7	8	9	10
Terrible										Superb

The dominance of personal qualities in what teachers believed made someone a good teacher suggests that personal dispositions are felt to be more important than professional skills. This could reflect a view that it is important to be a particular kind of person in the first place who can then develop appropriate professional skills. The following graph (Figure 5.5) compares the relative emphasis placed on professional skills and personal qualities from Question 6 (what kind of things do you think makes someone a good teacher?) against teachers' self rating as mathematics teachers in Question 8.

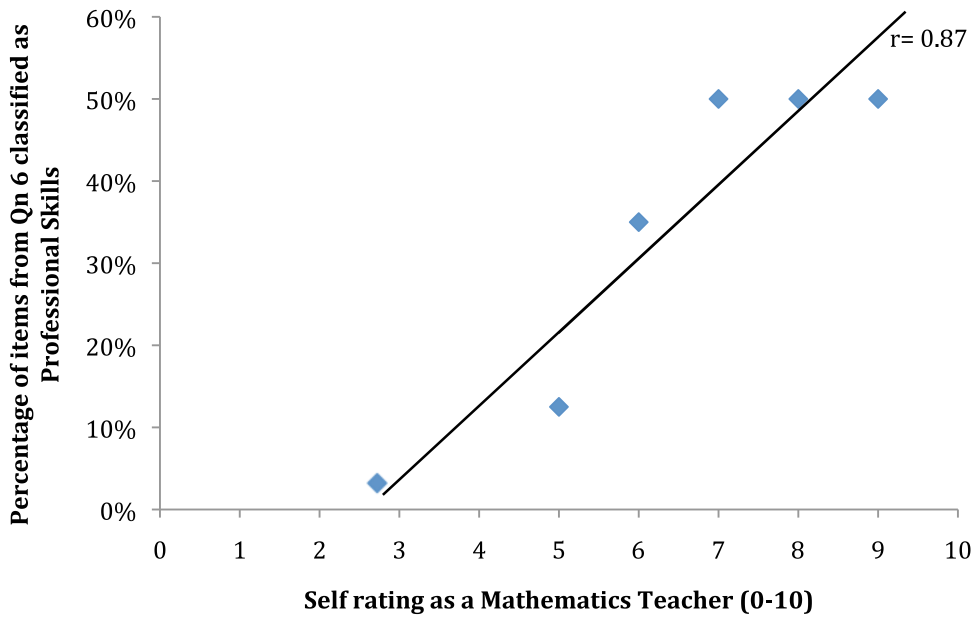


Figure 5.5 Plot of the proportion of responses to Qn 6 of Teacher Work survey categorised as Professional Skills against Qn 8 self-rating as a mathematics teacher.

This graph reveals a possible relationship (r=0.87) between the emphasis teachers place on professional skills over personal qualities in judging what makes a good teacher, and how they rate themselves as mathematics teachers. In particular it would seem that teachers who rank themselves lower as mathematics teachers place a reduced emphasis on professional skills and a greater emphasis on personal qualities, and conversely teachers who rate themselves more highly as mathematics teachers tend to emphasise professional skills over personal qualities in what makes someone a good teacher.

This seems to be consistent with the previous discussion around the more clinical *mythos* associated with mathematics, and reminiscent of the traditional distinctions made between the sciences and humanities, logical and intuitive, professional and personal. Mathematics is more readily associated with impersonal professional skills such as being organised, researching pedagogical theory, and catering for learning needs rather than with personal qualities such as compassion, humour, humility and so on. This is not to suggest that mathematics is devoid of personal qualities, even those who rated themselves highly as mathematics teachers provided equal numbers of personal and professional attributes in describing what constitutes good teachers. However, mathematics is often perceived as being more clinical than caring, perhaps making it unsurprising that those who have a diminished view of themselves as mathematics teachers place greater emphasis on personal qualities over professional skills.

On the other hand, it might be that this correlation captures something other than teachers' internalisation of the mathematics *mythos*. It could be that this difference in emphasis on professional traits between those who see themselves as good and bad mathematics teachers (cf. superb and terrible on the self rating scale) captures a difference in commitment to improving mathematics teaching, or a difference in willingness to work harder to become a more proficient mathematics teacher. It seems reasonable to assume that a willingness to make a greater effort to improve one's mathematics teaching would result in one becoming better at it. In turn this might reasonably be assumed to result in placing a greater value on certain acquirable professional traits, rather than placing the emphasis on innate personal dispositions. Thus, those who rate themselves more highly as mathematics teachers may place greater value on profession skills simply because they are willing to put in a greater effort to develop them, with the result that they feel they are good mathematics teachers. Some light can be shed on this matter by the third aspect of the Teacher Work survey where participants were asked about their working hours as a way of gauging teacher work loads.

5.3.1 Teachers' work patterns and self ratings as teachers

If teachers who rate themselves more highly as mathematics teachers do so because of a greater propensity to work harder it should be possible to observe differences in the responses to the first three questions of the Teacher Work survey which were as follows:

1. On average, what time do you tend to arrive at school?

2. On average, what time do you tend to leave school?

3. On average, approximately how many hours of work do you do outside of school each week?

Responses to these questions showed that on average teachers spent 9.2 hours at work each day, the minimum being 8 hours and the maximum 10.5 hours. Several teachers made additional comments to the effect that they often worked through their recess and lunch breaks as well. Adding in the time spent working out of school the weekly average was 53 hours with a standard deviation of 5.4 hours, a minimum of 42 hours, and a maximum of 60 hours.

In terms of any relationship between self rating as a teacher and the number of hours worked each week, no discernable pattern was evident. As can be seen in Figure 5.6 the plot of self rating and hours worked per week shows no obvious link between these two variables.

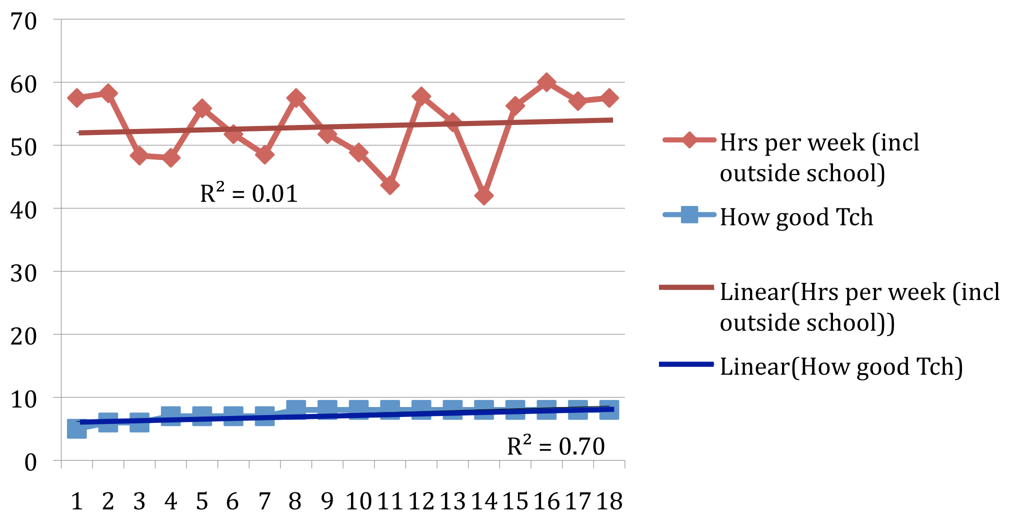


Figure 5.6 Graph of self rating as a teacher and total number of hours worked.

The data in Figure 5.6 are sorted by self rating from lowest to highest, but as can be seen, those working the longest hours each week represent both ends of the self rating spectrum, as well as in between. Assuming the data provided are accurate, this suggests that commitment and willingness to work hard are not factors in teachers' assessments of themselves.

The same can be said of teachers' self assessment as mathematics teachers. As Figure 5.7 shows, the hours worked by those who rated themselves lowest as mathematics teachers (ratings ≤ 6, n=8) compared to those who rated themselves the highest (ratings ≥ 7, n=10) are similar.

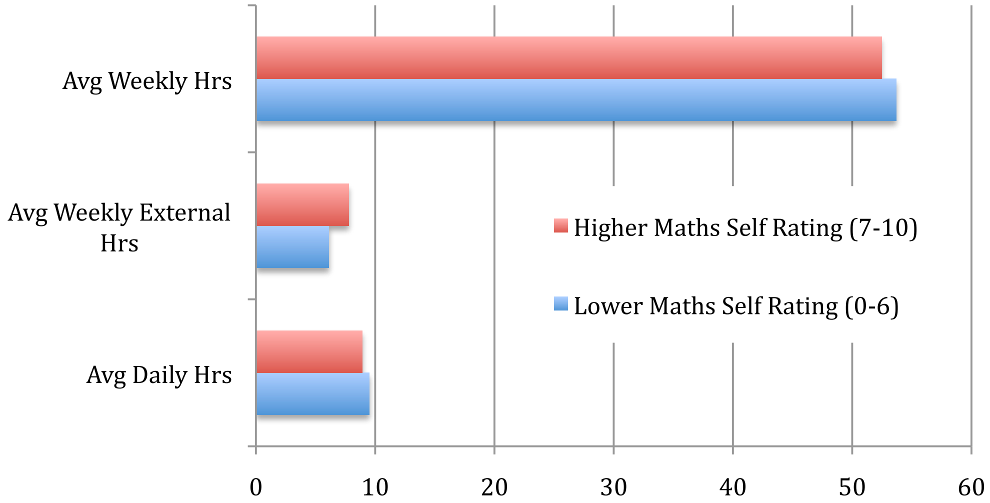


Figure 5.7 Graph of hours worked in a week broken down by self rating as mathematics teachers.

Other than for external hours, those who rated themselves lower actually worked slightly longer hours on average than those who rated themselves highly. This confirms that self rating of teaching ability does not appear to be linked to either the amount of time teachers spend at school nor how much additional work they do outside of school. In turn this invalidates there being a connection between work ethic and the observed relationship between emphasis on professional and personal attributes and self rating as mathematics teachers (see Figure 5.5).

If work ethic does not account for the differences in emphasis between the two groups of teachers, then perhaps it is possible that high rating mathematics teachers do have a value system that resonates more readily with attributes allied to the mathematics *mythos*, namely professional qualities rather than personal qualities, and vice versa for those mathematics teachers who rate themselves lower. This may tap in to an underlying disposition of mathematics teachers that could have much broader consequences in terms of their approach to teaching mathematics. Some of these issues are dealt with next.

5.4 ***Teaching and mathematics teaching self ratings***

As indicated above, many of the teachers participating in the TTML project felt that they were in some ways deficient in their teaching of mathematics. The last two questions on the Teacher Work survey asked teachers to self rate themselves on how good a teacher they believed they were and how good a mathematics teacher they believed they were.

7. How good a teacher do you believe you are?

0	1	2	3	4	5	6	7	8	9	10
Terrible										Superb

8. How good a maths teacher do you believe you are?

0	1	2	3	4	5	6	7	8	9	10
Terrible										Superb

Most individuals responded differently to these two questions demonstrating that these teachers distinguished between their abilities as teachers generally and their abilities as mathematics teachers specifically. Less than a third rated themselves equally on both questions, and although the sample size was quite small (n=18) a paired t-test of their ratings provided evidence to reject the null hypothesis that teachers' viewed their general teaching the same as their mathematics teaching (p=0.015). In fact one third of respondents rated themselves at least two points lower as mathematics teacher than they did as teachers (see Figure 5.8).

It is worth reiterating that whilst 18 teachers seems a small number, these are people who had persevered through the demanding TTML project over three years, having received substantial classroom focused input and many opportunities to develop, trial, and receive detailed feedback on both the content and mode of presentation of classroom mathematics units.

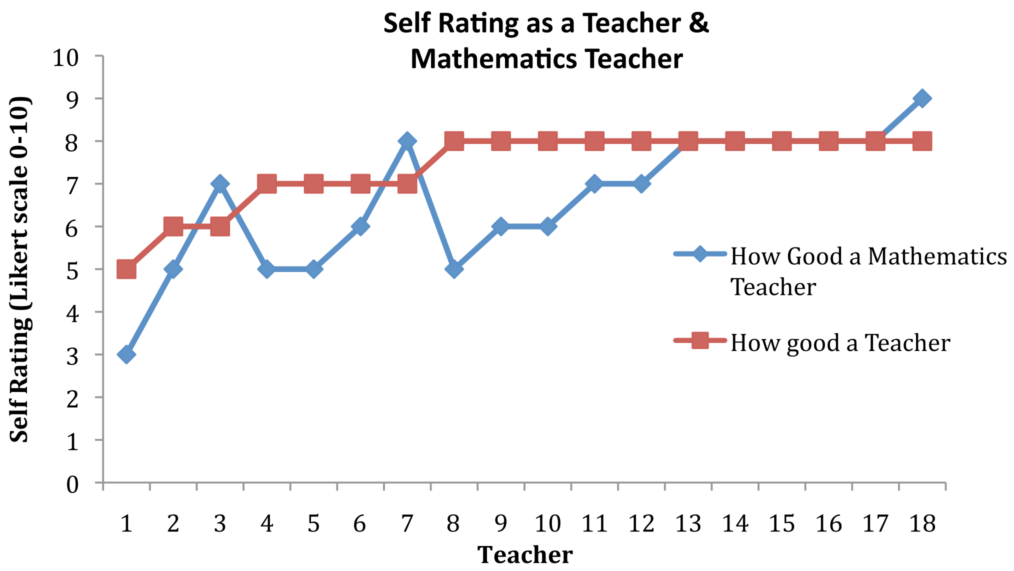


Figure 5.8 Results of teacher self ratings as teacher generally and teacher of mathematics

This graph shows that over three quarters of the teachers (78%) considered themselves to be better or worse mathematics teachers than they were as teachers generally, so it is clear that teaching mathematics is seen to be different from other forms of teaching. Interestingly, several of these teachers felt that they were better mathematics teachers than they were general teachers, suggesting that there may be a subset of teachers who particularly value mathematics. This is a point that is returned to in the next chapter.

Such variation may simply reflect the kinds of categories Shulman (1986) developed as distinguishing types of teacher knowledge. For instance, it would seem reasonable to assume that much of a teachers' general pedagogical knowledge (PK) is readily applicable to mathematics teaching, for instance their skills of classroom management, questioning techniques, and pacing of explanations would be equally applicable to all manner of content areas, including mathematics. Similarly it seems reasonable to assume that these teachers are aware of which aspects of mathematics need to be taught to satisfy the prevailing curriculum documents, as well as the variety of mathematics materials available to them to assist in doing so – so their curricular knowledge, or pedagogical content knowledge (PCK), is unlikely to be a major factor in them viewing mathematics and general teaching differently. However, Shulman's (1986) third category, subject content knowledge (SCK), is far more likely to be involved in explaining these discrepancies, along with the teachers' PCK as it relates specifically to mathematics, that is those ways of representing and formulating the mathematics to make it comprehensible to students. Thus, some teachers may have much stronger SCK which in turn bolsters their PCK, while other teachers with weaker SCK feel unable to fully develop the requisite PCK that would give them greater confidence in their mathematics teaching. It is interesting that this should still be the case after many years of teaching experience, and after having been involved in such a detailed mathematics professional development program for three years. It seems that there may be other factors at work besides SCK on its own.

5.4.1 Teachers' historical fatalism and mathematics anxiety

In a bid to further tease out some of the details behind these teachers' responses, the results of the survey were shared with them via email and a supplementary question was asked about whether they really did view teaching mathematics differently from teaching generally, and if so, in what ways.

Unsurprisingly, the responses to this question tended to revolve around the theme of lacking the requisite mathematical skills, or SCK. Those respondents who acknowledged ranking themselves lower as mathematics teachers indicated that they felt they possessed insufficient mathematical skills to be confident in their teaching of mathematics. For instance one such teacher replied,

> Sometimes…I have to research how to do the Maths as I have forgotten (sad but true…) or maybe never understood it in the first place and therefore feel unsure and don't want to give them the wrong info… This shakes my confidence in teaching maths to these students and therefore my opinion of myself as a Maths teacher. If I feel like a klutz I panic a bit – same with sport really!

While this lack of SCK as a major factor was readily predictable, what arose from these email responses was something beyond SCK itself. Interestingly such teachers appeared to not only have an expectation that they should have adequate SCK, but also that they should already have all of the SCK they need, and that they should be able to recall it immediately without recourse to revision or any refreshing of their understanding *I have to research how to do the Maths as I have forgotten (sad but true…)*.

It is to be expected that adequate PCK is predicated on sound SCK (although this is not always the case as is discussed below), yet what can pass as sound SCK may be no more than "arithmetic shortcuts and parlour tricks" (Gieger, 2007, p.97).

This may account for some confusion between having forgotten *or maybe never understood in the first place*, since rote learned techniques and tricks can yield correct answers in the absence of any deeper understanding. However, worse than this, if teachers do not see refamiliarisation with subject matter as a legitimate part of sound SCK, then they are stuck in a perpetual sense of inadequacy loop – they feel that having to relearn material is a sign of inadequacy rather than a sign of a someone who is mathematically competent. In reply to the teacher's email I shared a recent discussion I had had with a lecturer of undergraduate mathematics who had explained his need to revise certain topics that he only ever used when teaching a particular part of a course. The teacher responded that *I am heartened to hear that uni staff still do some revision too – that's made my day!!* This underscores what appears to be unrealistic demands such teachers place on themselves when it comes to mathematics, and hints at a certain mystique that seems to surround mathematics generally.

As a partial explanation for the confusion and mystique many associate with mathematics, Kogelman and Warren (1978) argued that mathematics does not lend itself well to group teaching formats which normally rely on discussion to help progress understanding, and that instead mathematical knowledge is emphasised "through lectures and drills" (p.24) with the answers to problems only ever being right or wrong. They went on to identify twelve myths often held by people suffering from mathematics anxiety. Two of the more common ones were that mathematics requires a good memory, and that some people have a "math mind" while others do not. These themes were identified by Franks (1990) when she surveyed 131 preservice mathematics teachers about their attitudes towards mathematics. She found that many expressed similar beliefs to those expressed by severely maths-anxious people, with over half expressing agreement with the two Kogelman and Warren (1978) myths regarding memory and *maths minds*.

It is not difficult to argue that the teacher quoted above also appears to subscribe to such views. The delight and/or relief expressed at hearing about a tertiary lecturer revising material is suggestive of having justified and even normalised their own need for revision. To have thought otherwise is indicative of the view that some people do not have to revise because they have a mathematical mind (lecturers) while others do not (those who have to revise). Similarly the belief that mathematics requires a good memory is implied by the fact that the teacher reports having forgotten their previously learnt mathematics, which, had her memory been better, she would have otherwise remembered.

Compounding these views is a kind of historical fatalism wherein failure and misunderstanding from the distant past continue to influence and impact negatively on the present. Simply because this teacher *maybe never understood it in the first place* she is still compelled to *feel unsure* of her abilities to teach mathematics despite being an experienced teacher who has taught the same or similar mathematical concepts many times throughout her career. Presumably she had to revise the material each time she covered it, which seems to have only served to feed her almost shameful (*sad but true*) sense of failure. This then impacts not only on her ability to teach, but reduces her professional and personal self esteem as well, at times reducing her to a state of panic.

So instead of viewing her revision of material as a strength indicative of personal resilience and resourcefulness correcting previous misunderstandings in the face of having *never understood it in the first place*, instead her efforts are further evidence of her original weakness, symptomatic of a poor memory or lack of a maths mind, locking her into a cyclical pattern to be repeated each time she needs to teach the material again.

This historical fatalism is also evident in this teacher's concern around giving students *the wrong info* as if this will somehow pollute their learning of mathematics forever – not unlike the way they seem to view their own early experiences as having been inescapably flawed in some way. This autobiographical theme emerged from other teachers' childhood experiences of mathematics as well. Several nominated having hated mathematics at school and wanting their own students to have a different experience.

> …as an adult I am anxious that kids don't dislike it as I did when at school and that makes me anxious to do my best job with teaching it… it is the more abstract, or not so practical maths that gets me in a twist.
>
> For me I guess it is very historical - I wasn't great at Maths in school and whilst I feel reasonably confident with Primary Maths, I have students who are working above level e.g Yr7/8 and I don't want to stuff them up.
>
> …for my self Maths and concepts were absolutely terrifying…I am a right brain person and still however, count with my fingers…

These teachers' experiences demonstrate just how potent school mathematics can be in terms of continuing to influence people for decades afterwards. Such experiences appear to be fairly commonplace amongst primary school teachers as seen in the work of Franks (1990), Dossel (1993), Chick (2002), and Wilson and Thornton (2005a, 2005b). Such research bears out anecdotal reports of pre-service teachers' anxiety levels being such that they throw up the night before mathematics tutorials. It is clear that some of these teachers have had discouraging, and in some cases traumatic experiences of learning mathematics which they do not wish to inflict on their own students.

It is not surprising that teachers who struggle with teaching mathematics due to their negative personal experiences of mathematics might privilege the personal dimensions of good teaching over those more in keeping with the mathematical *mythos,* the impersonal and professional aspects of teaching. It would also seem that the personal difficulties they experienced with mathematics continued to inhibit them developing further SCK and subsequently PCK. These teachers appear to form a distinct subset within the cohort of TTML teachers, and the next section explores another subset, those mathematics teachers who rate themselves highly.

5.4.2 Confident mathematics teachers and mis-learning

Two of those teachers who responded to the follow up emails identified themselves as having rated themselves as better mathematics teachers than as general teachers. Their responses had a distinctly different tone to the other responses. They presented themselves as being competent and confident mathematically, and were to some extent critical of other teachers.

> Over the years I have seen many teachers actually teach incorrect skills. I wonder what happens to the students of these teachers. It is often easier to teach the wrong method than the correct one. It is also difficult to unteach what has been taught. Perhaps mathematical logic is different to 'English' logic!

On this view other teachers were actively making this teacher's task more difficult through teaching incorrect skills. Once again the historical fatalism of the earlier, less confident, teachers is present, however in this case the fatalism is directed into the future in terms of *what happens to the students of these teachers* because it is *difficult to unteach* incorrect skills and methods. It would appear that once a student has mis-learnt something, it becomes a protracted problem for all concerned – not least the poor student whose future becomes uncertain.

It is not entirely clear whether the fact that it is *often easier to teach the wrong method than the correct one* is a reflection on the work ethic of those teachers doing so, or on the mercurial nature of the mathematics being taught, but in either case it appears to be a failing of these other teachers who are either too lazy to put in the effort to teach the correct method, or too lacking in SCK to understand the difference.

The other confident teacher of mathematics shared a recent experience of having a student teacher doing their final teaching round with her class.

> He was showing the students how to add, subtract and multiply fraction (after he had checked with me) and one of the students asked how to divide fractions. He told them they didn't need to know that in year 6 but told me later he had no idea! (I showed them yesterday).

This teacher seems to echo the concerns of the previous teacher with the student teacher's lack of robust mathematical knowledge. While such concerns are consistent with Shulman's (1986) categories of what constitutes required teacher knowledge, as Bishop (1976) pointed out earlier, classroom decisions are important too, and it seems that in this instance the student teacher chose the path of self preservation in terms of hiding his lack of knowledge from the class rather than incorporating his lack of SCK into the lesson. It was, perhaps, a missed opportunity to actively model for the class how to constructively deal with a gap in mathematical understanding, but the student teacher, quite reasonably, lacked sufficient confidence to make himself vulnerable in this way. It seems that instead he attempted to give/preserve the impression that he actually knew how to divide fractions, but that it was just unnecessarily difficult for Grade 6 students to worry about at the moment.

Interestingly the next day the supervising teacher managed in one parenthetic swipe to potentially both undermine the student teacher's credibility with the class whilst at the same time bolstering her own credibility since she knew how to divide fractions and was prepared to induct the class into this esoteric knowledge too. We are not privy to how such information was conveyed to the class, nor how much they received, or whether the student teacher was present or not, but it is sufficient for this purpose to note that the class was essentially being protected from an instance of perceived mis-teaching and potential mis-learning.

In summary, both confident and unconfident teachers seem to be concerned with mis-learning as a result of mis-teaching. While those teachers who rated themselves more highly as mathematics teachers also tended to rate themselves more highly as teachers generally (r=0.64, see Figure 5.9), the majority of teachers rated themselves lower as mathematics teachers than as teachers generally, despite for the most part having been involved in the TTML professional development project for the previous three years.

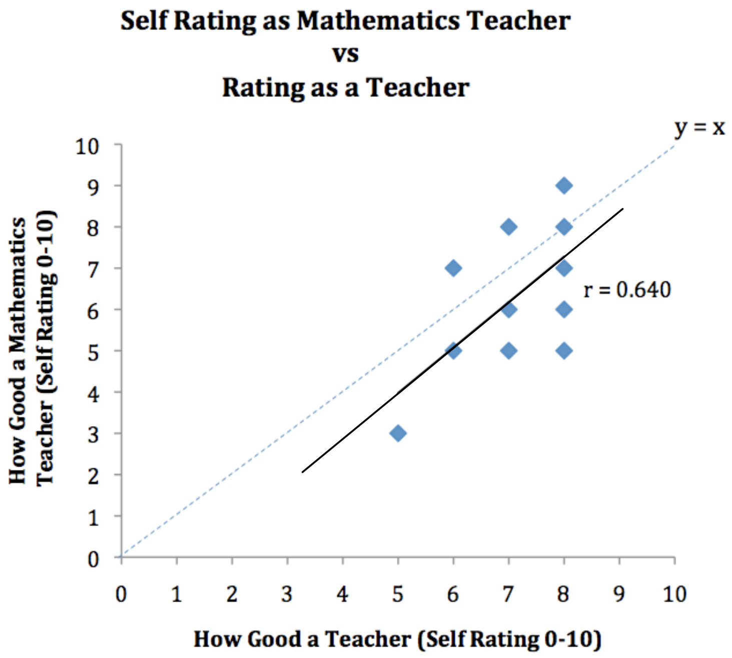


Figure 5.9 Plot of teacher self ratings.

This chart clarifies the gap between teachers' self rating as teachers and as mathematics teachers. The majority of responses are below the y=x line where if teachers felt equally confident about their teaching, regardless of content, one would expect a clustering of dots along the y=x line. However the fact that most of the dots fall below this line illustrates the lack of confidence these teachers still feel about mathematics, as demonstrated by their concerns about mis-teaching their students, and the importance of doing a good job.

5.5 ***Overview of the chapter***

The data collected from the Teacher Work survey provide some insights into the population of dedicated teachers. The 18 respondents were committed, well informed practitioners who had all had similar experiences throughout the TTML project. Unlike a survey of 18 randomly selected teachers, this group represent a unique data source of teachers who are substantially interested in improving their pedagogy.

The results of the survey appear to suggest that teachers are to a large extent inwardly focussed when assessing their own performance. Professional development seems not to be valued particularly highly by teachers in terms of judging the quality of their teaching, and personal qualities account for between 50% and 90% of what teachers believe are important to being a good teacher. Professional factors are rated more highly by those who rate themselves more highly as mathematics teachers, but overwhelmingly teachers look to their students and immediately accessible sources such as parents, colleagues, and annual reviews to evaluate their performances.

Arguably this might demonstrate a link that exists for teachers between professional skills and SCK, since those teachers who feel confident of their mathematics teaching (high SCK) value professional qualities, while those who lack confidence in their mathematics teaching (lower SCK) do not value professional attributes to the same extent. If this link exists there are implications for professional development since many of those who are most likely to benefit from increased SCK and improved professional skills are those who value them least. It could also imply that emphasising these areas alienates low SCK teachers – perhaps the kind of teachers who do not wish to be observed in class.

Teachers share mathematics education researchers' concerns about doing a good job of teaching mathematics, however unlike researchers who tend to focus on the mathematics and professional aspects of teaching, those teachers who worry that they may not be doing a good job appear to value personal qualities of teachers over professional qualities. This might account for why their concerns about mis-teaching mathematics do not impact on their sense of teaching generally, that is, even though they do not consider themselves to be particularly good mathematics teachers, they still consider themselves to be good teachers generally since it is their personal qualities rather than SCK that enables them to do a good job.

This distinction between an emphasis on the personal or the professional may parallel the kind of difficulties students encounter with mathematics. Some have argued that the disposition of a child (Feeling vs. Thinking/Practical vs. Theoretical) can result in flawed strategies for dealing with basic numeration. For instance Neuman (1997) explored the contradictory observation that some children would arrive at school on their first day knowing how to subtract, but that two years later they were unable to answer mathematics subtraction problems within the 1-10 range. It seemed that either two years of schooling had deprived them of abilities they arrived with, or that they failed to connect their intuitive understandings with formal mathematics. Ginsburg and Asmussen (1988) pointed out a similar quandary, that "the vast majority of children and adults possess sound basic intellectual processes – skills in reasoning, abstraction, memory and the like" (p.90) but that somehow children (and some adults) struggle to learn something that would appear to be no more than an extension and formalisation of what they already know.

This might account for some the mathematics anxiety that appears to exist within this cohort of teachers. The observed historical fatalism seems to arise from teachers' own childhood experiences of mathematics, which may in turn arise from a fundamental distinction in cognitive styles, for instance the dominance of a feeling and/or practical style of cognition rather than a more abstract thinking style. It may not be the case that either style is more or less able to learn mathematics, but it may be that mathematics presented in one style alone disadvantages those who process concepts in a different style. This is closely related to Gardner's (1983) notion of multiple intelligences and the argument that teachers need to cater to the different learning styles of their students.

Whatever the actual underlying cause, some teachers clearly connect their current concerns with teaching mathematics to their own experiences of learning mathematics at school. This is suggestive of an intergenerational cycle of difficulties with school mathematics. That is, despite these teachers working long hours, appearing to be reflective and willing to engage in self evaluation, there remains concerns about many of their mathematics skills which seem to date back to their childhood. These difficulties may in turn adversely impact on their students who, if they become teachers, may end up in a similar position and perpetuate the cycle with their students.

The fact that teachers have reported views consistent with them suffering from mathematics anxiety, and at the other end of the spectrum there appearing to be teachers who are concerned about potential mis-learnings of students brought about by the mis-teaching of less able colleagues, suggests there are grounds to be concerned about there being equitable learning opportunities for all students. Some of these issues are explored further in the next chapter.

CHAPTER 6

Educational inequity and school mathematics

Mathematics is held in high regard within the community, so ensuring students have equal learning opportunities is important. The populace of Gold Hill perhaps exemplify the near ubiquitous regard held for mathematics - numbers matter almost regardless of what they mean. The argument pursued in this chapter attempts to show that there is a broad array of ways in which mathematics may be inequitable across gender, ethnic, and social lines, and that in addition to, and likely compounding these other risks for students, is a type of random inequity that could arise from differences in mathematics teachers' knowledge and attitudes toward their students.

Many studies have demonstrated that all students, regardless of background, can learn mathematics when given high-quality, supportive mathematics programs

(Campbell 1995; Silver & Stein 1996). And while there are mathematics teachers we might wish were more confident or knowledgeable or sympathetic to students, it is important that the task of teaching mathematics is ultimately doable by humans. And doable in a way that is equitable to students. There will always be individual variations in any given teacher's ability to deal adequately with subject matter to a greater or lesser extent. For instance, it would be rare for an English teacher to struggle with knowing how to read, or write, or understanding a novel or poem, although the same is not always true of teachers of a foreign language, particularly where teachers who lack fluency are sometimes tasked to teach the language, or more commonly, the 'culture' of the target language. This is an unfortunate situation that can all too easily alienate students from the pursuit of languages other than English. Yet it is largely a non-issue from the perspective of the broader community because of the Anglocentric nature of our society. However, mathematics occupies a larger place on the academic and curricular landscape and as a result it is considerably more important to students whether their teachers are 'fluent' or not. But mathematics has become something of a juggernaut, with an enormous amount of content that teachers feel compelled to rush through in a bid to cover all the material expected of them, regardless of their own, or their students', understanding of that material. Teachers who lack confidence in their own understanding of mathematics potentially compound the problem even further for their students.

This chapter is divided into three sections. The first, Section 6.1 gives a brief overview of some of the main aspects of inequity researched to date within mathematics education. The argument pursued in Section 6.2 is based on the analysis of survey data collected from TTML teachers relating to their confidence in teaching mathematics, mathematical knowledge, and views of students. Section 6.3 goes on to suggests there may be an arbitrary mechanism of inequity arising from the limited fluency of some mathematics teachers alluded to above. This systemic inequity, that I refer to as *random inequity,* could result in the relative educational disadvantaging of many students. Overall this Chapter argues that there may be potentially insoluble issues with school mathematics education that make inequitable outcomes inevitable.

6.1 ***Mathematics education and equity***

Concerns about the equitable nature of mathematics education have been investigated for many decades as part of a broader critical sociology of education (Apple, 1979). Amongst the most prevalent concerns relating to equity are those relating to sex, ethnicity, and social economic status (SES). These concerns assert that analysis of student participation in mathematics courses, and performance on large scale mathematics assessments, have revealed that girls, minority groups, and those with low SES backgrounds are under-represented, and under-perform, in mathematics compared to boys, majority groups, and students from more affluent backgrounds respectively. The general principle behind such analysis is that mathematics should be a meritocratic based system, blind to gender, race, social status, and any other systematic social distinctions. In recent times there has also arisen a concern with cultural bias inherent in mathematics education and efforts have been made to acknowledge culturally diverse approaches to mathematics in a field that has come to be known as ethnomathematics.

The following is not intended to be a comprehensive review of the vast literature on gender, social, and racial inequity but rather an overview to help illustrate the kinds of experiences and/or difficulties students might face at school. Gender and racial based inequities are covered briefly in 6.1.1 while 6.1.2 looks at broader social inequity influences. Some of the responses to these forms of inequity are looked at in 6.1.3.

6.1.1 Mathematics and inequity based on gender and race

Research into the disparities between participation and performance in mathematics based on the gender and racial background of students has been underway since at least the 1970s. Many theories have been explored in an attempt to understand the mechanisms underlying observed differences in the rates at which girls and minority groups took up more advanced mathematics courses compared to boys and dominant racial groups, and the disparities between these groups in performance in certain areas of mathematics.

Fennema and Sherman (1976) developed their Mathematics Attitude Scale which contained a sub-scale explicitly addressing students' perception of mathematics in terms of gender, the 'Mathematics as a Male Domain' (MD) scale.

It was later reported that this scale showed the greatest gender based difference in responses from students, and that the inferred underlying stereotype of mathematics as a masculine pursuit was something that girls needed to overcome if they wished to succeed at and/or pursue mathematics further (Hyde, Fennema, Ryan, Frost, & Hopp, 1990).

Teacher beliefs and pedagogical practices have been critically examined to uncover ways in which these may have impacted on girls and boys differently in mathematics classrooms (Boaler, 1997). It has been claimed that because girls have 'connected' learning styles (Gilligan, 1982), and that they prefer contextualised information in solving problems, they therefore have been effectively excluded from mathematics because of it being often presented as a series of disconnected, abstracted techniques, and discrete topics (Becker, 1995). Similarly, girls are reported to prefer cooperative and supportive working environments whilst boys prefer competitive, high pressure ones, and it is the latter which has more traditionally been associated with higher level mathematics classrooms (Head, 1996).

In addition to the psycho-social research into gender differences there has been a body of work surrounding biological differences between girls and boys such as spatial ability (Benbow & Stanley, 1980). However, more recently there have been a number of studies claiming that such differences have disappeared over time (Baker & Jones, 1993; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Else-Quest, Hyde, & Linn, 2010), and in some places reversed (Dindyal, 2008), which would tend to preclude organic explanations for any observed differences in attainment between the sexes.

While these reports of a narrowing or elimination of the mathematical gap between boys and girls have been welcomed, some researchers have cautioned against complacency, and in some instances believe that there may still be issues that are masked by other factors. For instance Forgasz, Leder, and Gardner (1999) argue that the Fennema-Sherman MD sub-scale is no longer valid given the shift in community mores, and because of a flaw in its original conception which forced students to respond only in terms of mathematics as a masculine domain, leaving no room for them to conceptualise and express their view of mathematics as a feminine domain. However, other researchers have claimed that the gender equity debate is largely resolved, for instance Chipman (2005) has stated that by the time the problem of young women and mathematics was raised in the literature “the ‘problem’ had already diminished significantly, and that trend has continued until the present time” (p.5).

Whilst there may be some doubts about whether the gender inequity debate within mathematics captured an organic, social, or even significant phenomenon, there can be no doubt that it represented a subset of the broader feminist critiques that arose in the last forty years and helped to raise awareness for the potential of systemic inequities to exist within mathematics education and demonstrated that there was scope to tackle inequity through various interventions.

The complexity of the equity issues surrounding mathematics is highlighted by the kinds of results reported by Yando, Seitz, and Zigler (1979) wherein African American male students were found to underperform compared to African American female students, while as a group the African American students underperformed compared to their white peers. Similarly, recent national testing in Australia has shown a significant proportion of Indigenous Australian students perform below national benchmarks in numeracy, as well as an over-representation of students with languages backgrounds other than English below these benchmarks (Commonwealth of Australia, 2010).

The Program for International Student Assessment (PISA) 2006 results (Thomson & De Bortoli, 2007) relating to mathematics performance of 15 year olds indicate that socioeconomic status (SES) is strongly correlated with school achievement, with 29% of students from high SES backgrounds performing at the highest level, nearly five times as many as low SES students. Virtually the reverse was true for those performing at the lowest two levels, where 22% of low SES backgrounds were assessed, over four times as many as for high SES students. Thomson and De Bortoli’s (2007) report demonstrates the diversity of mathematics skills that can exist within a single class, simultaneously increasing the pressure on teachers to cater to a greater range of abilities whilst also increasing the difficulty of doing so.

Many schools address this issue of diversity by grouping students by ability, either for all of their subjects, or just for mathematics. This streaming has been widely criticised, for instance Hattie (2009) notes that meta-analyses of over 300 studies shows streaming to have “minimal effect on learning outcomes and profound negative equity effects” (p. 90).

A similar, but greater, disparity in performance based on SES background exists when the results of Indigenous and non-Indigenous students are compared. Here only 2% of Indigenous students perform at the highest level while 39% are assessed in the lowest two levels. Clearly there is a need to find ways to address the differences in outcomes generally, and to overcome factors that appear to be inhibiting the learning of particular groups of students.

One way of improving mathematics teaching for Indigenous students involves identifying particular characteristics of the culture of the students and using those characteristics to inform pedagogy. For example, Cooper, Baturo, and Warren (2005) argue that modern curriculum can alienate Aboriginal children and have developed ‘two way learning’ curriculum that shows the value of making mathematics more accessible, connected and meaningful to all students by mixing modern and Indigenous knowledge.

Another approach has been to recognize that the sort of parental support with homework and developing positive attitudes to schooling that non-Indigenous students often receive is not always available for Indigenous students. Various projects have tried not only to incorporate community values into teaching approaches, but actively engaging Indigenous communities in aspects of the curriculum and pedagogies that are adopted. Frigo, Corrigan, Adams, Hughes, Stephens, and Woods (2003) report that positive outcomes are associated with strong school leadership in partnership with local Indigenous leaders and Indigenous presence in the school, initiatives that support regular attendance, and supporting the active engagement of students in their learning.

Jorgensen and Sullivan (2010) report an initiative using focused teaching and sensitive pedagogy, the Maths in the Kimberleys project. This approach involves two complementary strands that examined a collaborative group pedagogical approach and a focused teaching approach that actively builds on assessments of what the students do and do not know. They argue that teachers should articulate the goals of teaching to the students and thoughtfully sequence activities that build from what the students already know.

The theme in all such studies is that teachers should recognise differences in background and learning styles, the principles and strategies of which are directly applicable to all low achieving students. So while the last fifty years has seen a great deal of effort invested in understanding the nature and causes of gender and ethnic based inequity in mathematics education, in many ways these forms of inequity are particular instances of broader inequities inherent in our social structures, which are examined next.

6.1.2 Mathematics and inequity based on social characteristics

Given the social disadvantage experienced by many minority racial groups, the phenomenon of racial inequity may well be compounded by, or at least a subset of, broader social inequities that appear to occur within education, or what Willis' (1977) book aptly captured with the title of his book *Learning to Labour: How working class kids get working class jobs*. The inequitable nature of schooling was further highlighted by the work of Ginsburg and Russell (1981) who claimed that all students investigated in their study of four and five year old children, regardless of race or socioeconomic background, had the requisite cognitive skills to perform adequately in mathematics. They also found that students from low SES backgrounds outperformed middle class students on mathematical tasks requiring creativity, while the reverse was true for tasks more like those traditionally used in classrooms. However, as students spend more time in school disparities between the groups grew.

Teese (1995) argued that students of tertiary educated parents benefit from higher parental expectation combined with "residential segregation on social lines" (p.53) that effectively produced mono-cultural classrooms of higher motivated students and subsequently greater levels of teacher satisfaction. He claimed that such environments provided ideal circumstances for the teaching of highly structured subjects like mathematics, and the absence of such environments in the classrooms of low SES students placed them at a distinct educational disadvantage.

Analysis of student performance on the 2003 PISA (Thomson, Cresswell, & De Bortoli, 2004) and the Trends in International Mathematics and Science Study (TIMSS) (Australian Council for Educational Research, 2006) showed considerable differences between student performance depending on geographical location within Australia. Some have described the statistically significant discrepancies between the performance of metropolitan, rural, and remotely located students as a "chasm" (Panizzon & Pegg, 2007). Similar variations have been detected by the National Assessment Program – Literacy and Numeracy (NAPLAN) testing

(Ministerial Council on Education, Employment, Training and Youth Affairs, 2007).

It seems clear that there is an entrenched mathematics inequity based on social stratification and geographical location. Given the greater proportion of Indigenous Australians living in remote and regional areas, any race based inequities could either be a function of these social inequities, or compounded by them. Either way there appears to be distinct advantages for some students over others depending on their postcode.

6.1.3 Responses to inequity

There is no doubt that issues of inequity are taken seriously by the research community and educational authorities. The Victorian Government has a detailed policy to develop "a strong pool of talented scientists and mathematicians to advance technological and scientific boundaries" (Department of Education & Early Childhood Development 2009a, p.5) and is building dedicated mathematics and science schools to provide specialised mathematics and science education. At a national level the Commonwealth Government has committed $540 million to making improvement in literacy and numeracy outcomes. This represents one of the latest attempts of many that have been made to bridge the kinds of gaps that have been highlighted over the past forty years. Single gender mathematics classes have been formed in an effort to better cater to the identified learning preferences of males and females, textbooks have been edited to include either gender/race neutral or gender/race inclusive terminology, parents have been encouraged to extend the range of their expectations for their daughters (McAnalley, 1991), teacher education courses have been modified to make explicit and multi-culturalise the values being taught in school mathematics (Bishop, 1997), attempts have been made to deliver social interventions in the form of affirmative action tertiary selection policies (Rom, Locker, & Seidman, 1991), and the development of television shows such as *Sesame Street* in a bid to target disadvantaged communities and 'close the gaps' they experience relative to privileged groups in the community (Austin, Preston, Ward, Eldon, Riggins, & Salyer, 1977).

However, few of these efforts have been seen to be effective, and some have been accused of actively worsening the situation. For instance, *Sesame Street* has been associated with actually widening the gap between disadvantaged and privileged groups due to its popularity with children from all backgrounds and the capacity of advantaged families to leverage greater benefits for their children from it (Cook, Appleton, Conner, Tamkin, & Weber, 1975). Similarly, the focus on efforts to encourage girls in mathematics led some to raise concerns about the exclusion of boys (Garner, 1999). Thus attempts to improve participation or performance of one group may have unanticipated negative impacts elsewhere.

As a result the realm of mathematical equity remains fraught with difficulties. The interplay between gender, racial, and other social biases appear to contribute to patterns of inequity and limited opportunities that effect many students. Sincere efforts have been made to rectify many of these inequities, however compounding these areas of concern, particularly in low socio-economic settings, may be another type of inequity that derives from the availability of skilled mathematics teachers generally. This is explored in Section 6.2 below.

6.2 *Mathematics education and random inequity*

The issue of inequality within mathematics education has been an important area of research for many decades, however the focus has usually centred on identifiable sub-groups of the community based on gender, ethnicity, and location. Analysis of TTML data provides evidence for the existence of another, more general, form of mathematics education inequity. Survey data relating to teaching workloads and teacher self perceptions were explored in the previous chapter, but there are aspects of those results which are relevant in the current discussion, particularly those concerning teacher confidence and mathematical subject content knowledge. The survey data presented previously showed a number of the teachers rated themselves as better teachers generally than as mathematics teachers. This suggested a lack of confidence in both their skills as mathematics teachers and their knowledge of the mathematics they were teaching. Section 6.2.1 explores additional data collected from a survey administered at the beginning of the TTML project to 92 teachers. Some possible implications for the educational equity of students encountering such mathematics teachers is then explored in 6.2.2

6.2.1 Estimating the prevalence of less effective teachers

It is assumed here that there is a plausible link between mathematics teachers who might be considered to be less effective in terms of their students' learning and those who report both low levels of confidence in teaching mathematics and low levels of mathematical content knowledge. It needs to be borne in mind that these measures remain, at best, a proxy for whether such teachers do in fact represent a source of disadvantage to their students.

6.2.1.1 Teachers reporting low confidence and low subject content knowledge

The questions from the Teacher Work survey explored in the previous chapter gave some indication of the prevalence of less confident and less knowledgeable mathematics teachers. Additionally, several of these teachers appeared to exhibit a form of social phobia related to mathematics, or maths anxiety (Ashcraft, 2002). As we saw, a number of these teachers reported concerns about the impact their lack of mathematics proficiency could have on their students, and similar concerns for their students were voiced by other, more confident and knowledgeable teachers.

At the beginning of the TTML project an initial survey (see Appendix IV) was administered to a group of 92 teachers. These teachers were a mixture of TTML participants and other non-participants who served as a control group. It is instructive to consider a graph of teacher self ratings of confidence in teaching mathematics against knowledge of mathematics based on their responses to Questions B1 and B2 (see Figure 6.1).

B1. Rate your knowledge of mathematics for teaching mathematics at this level

0	1	2	3	4	5	6	7	8	9	10
Poor										Excellent

B2. How confident do you feel in your teaching of mathematics at this level?

0	1	2	3	4	5	6	7	8	9	10
No confidence										Highly confident

It is clear that a number of teachers felt under-confident, and some over-confident, relative to their stated levels of subject content knowledge, which is consistent with the results discussed in the previous chapter relating to self-ratings as mathematics teachers and as teachers generally on the Teacher Work survey. However, there were a group of teachers in this larger survey who reported both a lack of knowledge and confidence that is potentially indicative of a group of mathematics teachers who jeopardise their students' learning, which could reasonably be seen as a cause for concern from a student equity perspective.

It is worth noting the strong correlation between responses to these two questions, with 73% of variation in one being explained by the other (r^2=0.73). This reinforces the connection between teachers lacking SCK and feeling that they are not effective mathematics teachers, as discussed previously in Chapter 5.

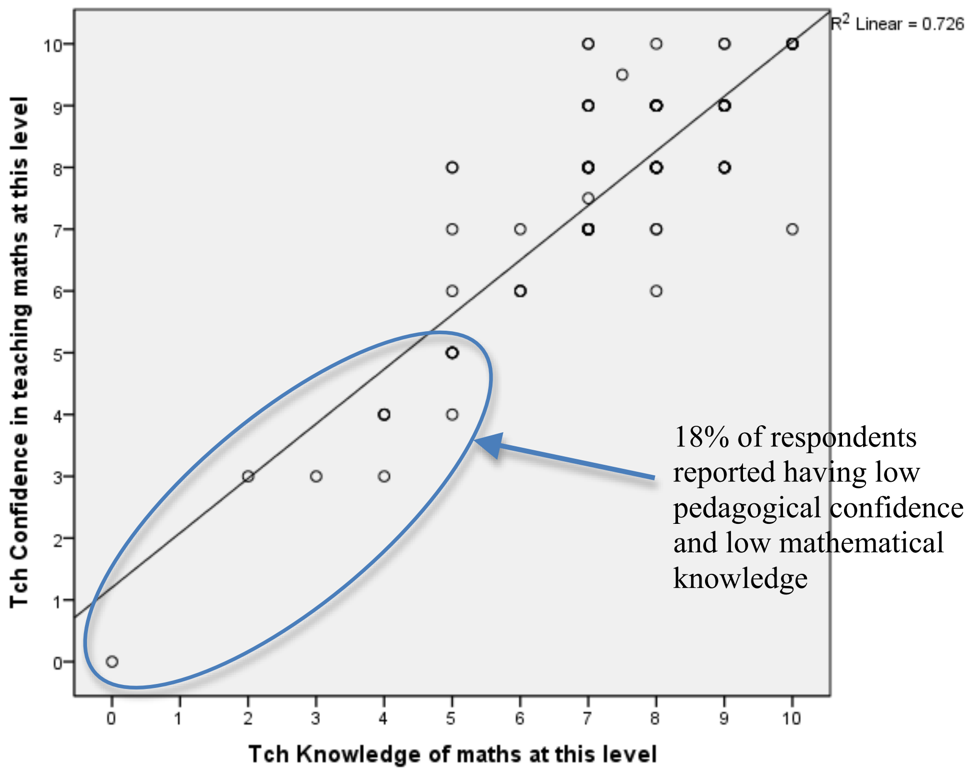


Figure 6.1 Relationship between teacher responses to Questions B1 and B2 of the TTML teacher survey. Note that darker circles represent multiple teacher responses.

Of the 92 respondents 18% indicated knowledge and confidence levels of 5 or less on a scale of 0 to 10 – these responses are circled in Figure 6.1. For the sake of advancing the argument at hand the combined low self-ratings of confidence in teaching mathematics and low self-ratings of mathematics knowledge to be taught are taken as a proxy for such teachers jeopardising the achievement of their students in the sense that their students are likely to have been at an educational disadvantage relative to their peers who had more confident and knowledgeable mathematics teachers.

Note that this discussion of educational disadvantage is couched in relative, not absolute, terms. This relativity has two aspects to it. First, it may well be the case that in absolute terms even the lowest self rating teachers are highly effective mathematics teachers. The high ranking of Australia in international studies like TIMMS (Australian Council for Educational Research. 2006) might support such a conclusion since the high performance of Australian students by international standards suggests that Australian teachers have been effective at providing mathematics education, regardless of how they feel about their pedagogical abilities personally.

However it is the second aspect of this relativity that is the crux of the matter. Because the Australian education system is driven by a competitive *telos*, it does not matter how well Australian students fare in absolute or quasi-absolute terms (internationally for instance). What matters is how students compare to each other since they will be ranked at the end of Year 12 to determine who will gain access to tertiary level study, and mathematics is a pre-requisite for entry into many prestigious courses and career paths (Victorian Tertiary Admission Centre, 2010). Thus, what matters from an equity perspective is not absolute mathematical skills per se, but rather how students' mathematics skills compare to those of their peers. It is this sense in which mathematical equity needs to be considered, as this is how students will ultimately be compared and judged. It is here that teacher self perception may be considered to have a greater impact in that students of mathematics teachers who feel less confident and less knowledgeable are plausibly at an educational disadvantage compared to students of those teachers who feel both knowledgeable about the mathematics they are teaching and confident in teaching it. In this sense it does not matter what the scale of the disadvantage is in absolute terms, but that the disadvantage exists at all. For instance, the rankings of participants in Formula 1 car races might span a few minutes while the rankings of yacht race competitors can cover many hours or days, but whether Australian mathematics teachers are akin to racing cars and South African mathematics teachers are more akin to yachts is irrelevant. What matters is that the students are compared to each other within their own system (Formula 1 versus Formula 1), not across systems (Formula 1 versus a yacht).

It seems reasonable to conclude on the strength of this evidence that there is a group of teachers who lack both pedagogical confidence and mathematical content knowledge that could be a source of educational disadvantage to their students. Yet, this may not be the only source of educational disadvantage for students as is explained next.

6.2.1.2 Teachers reporting high confidence and high subject content knowledge

In addition to the teachers who gave low confidence and low knowledge responses, there are data from a different group of teachers whose responses to the TTML teacher survey suggest that they too could be considered an equity risk, that is, their students might plausibly be considered to be educationally disadvantaged relative to their peers. This other group of teachers typically rated themselves highly in terms of pedagogical confidence and mathematical knowledge. The way in which they might be seen to be disadvantaging their students revolves around the way in which they perceived their students generally, and unmotivated students in particular.

The responses to Question B3 of the initial TTML survey suggest that there are a subset of confident knowledgeable teachers who harbour quite pessimistic views of their students compared to other teachers, which when coupled with the notion of *self-fulfilling prophecy* (explored further in Section 6.2.1.3 below), potentially constitutes yet another type of teacher who place students at a relative disadvantage. Question B3 asked about working with unmotivated students and an analysis of the responses to this question was undertaken to explore how confident knowledgeable teachers felt in dealing with such students.

B3. How confident do you feel in your ability to address the needs of learners who seem unmotivated in mathematics?

0	1	2	3	4	5	6	7	8	9	10
No confidence										Highly confident

The responses to this were only weakly correlated to teacher responses relating to mathematics knowledge as reported in Question B2, with $r^2 = 0.13$ (see Figure 6.2). This lack of a clear trend suggests that confidence in dealing with unmotivated students requires skills beyond subject content knowledge alone.

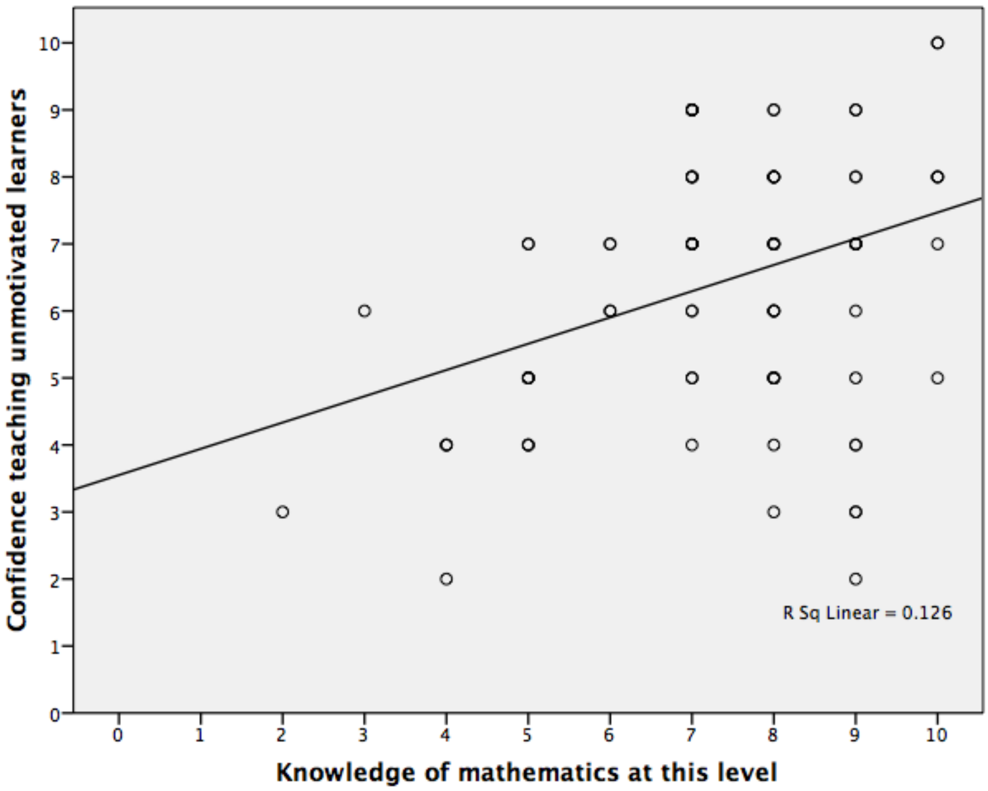


Figure 6.2 Graph of responses to Questions B2 and B3 on the initial TTML survey. Note that darker circles represent multiple teacher responses.

While there are few teachers who report low mathematics knowledge and high confidence in dealing with unmotivated students, there are many who report high mathematics knowledge and low confidence in teaching such students. This reinforces the impression that increased SCK does not necessarily assist with dealing with unmotivated students.

In exploring issues of equity it is particularly relevant to focus on the responses to these questions since unmotivated students may already be labouring under the influence of one or more sources of mathematics educational inequity, so as a group they represent the kind of students most at risk of permanent mathematical disengagement. To these ends it is instructive to analyse additional survey data which relates to the constraints teachers felt impacted on their ability to teach effectively. In particular, survey items dealing with constraints associated with student qualities seem especially relevant.

The TTML survey contained two such items within question C4, and a further 17 in question D1 that focussed on other student characteristics (these are dealt with later in this section).

C4. Indicate how often the following stops you from teaching mathematics as well as you want to.

		Hardly Ever	Now and Again	Quite Often	Nearly Always
e.	As soon as the work gets difficult, the students give up	1	2	3	4
f.	The students are not interested in learning	1	2	3	4

Responses to C4.e and C4.f were matched to responses to questions B1 (knowledge of mathematics), B2 (confidence teaching mathematics), and B3 (confidence teaching unmotivated students). This revealed interesting, and statistically significant, patterns which can be seen in Figure 6.3.

These graphs are based on four groups of teachers: those who chose ‘Hardly Ever’ (1), ‘Now and Again’ (2), ‘Quite Often’ (3), and ‘Nearly Always’ (4) for questions C4.e and C4.f. Each of these groups are represented along the x-axis of the graphs. The mean responses of each of these four groups to B1 (green), B2 (blue), and B3 (brown) is then plotted along the vertical axis. The connecting coloured lines are purely visual aids and do not represent any intermediate values, but serve to help distinguish the responses to each question.

What is revealed by these graphs is that there were no notable differences between the four groups in terms of reported levels of confidence in teaching mathematics or mathematical knowledge, as is evident by the near horizontal nature of the blue and green lines. However, there is a significant difference between the responses of those who felt confident teaching unmotivated students and those who did not, with the brown line falling sharply as the groups’ frequency of feeling impeded rise (i.e., as each groups’ reported level of being impeded changes from ‘Hardly Ever’ (1) to ‘Nearly Always’ (4)).

Just to be clear, the brown lines illustrate that teachers who believed students ‘Nearly Always’ gave up (C4.e) and are ‘Nearly Always’ uninterested in learning (C4.f) reported much lower confidence in teaching unmotivated students than teachers who thought students were ‘Hardly Ever’ interested or gave up when work got difficult.

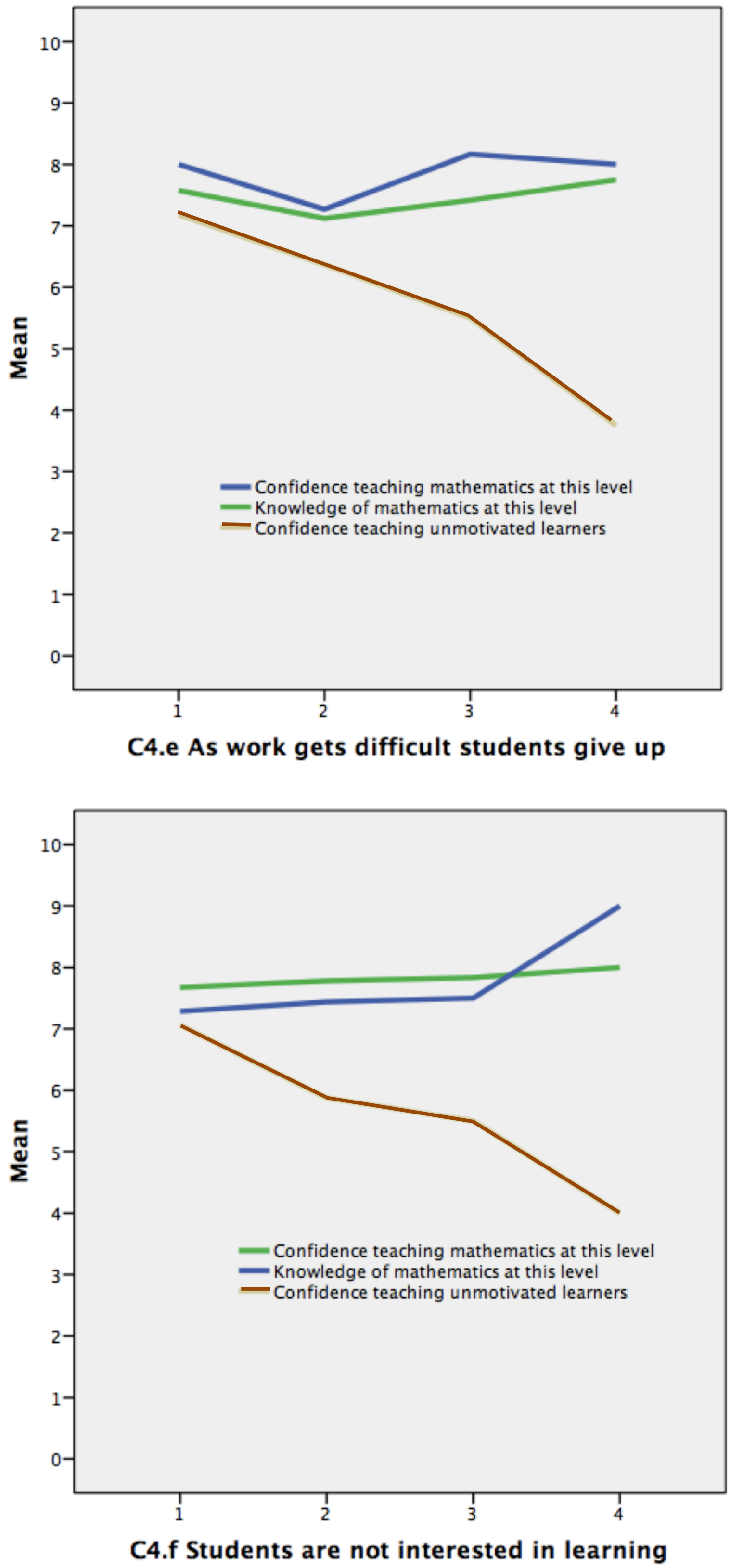


Figure 6.3 Comparisons of mean responses of teachers to questions B1, B2, and B3 of the TTML survey grouped by their responses to questions C4.e and C4.f.

Those teachers who indicated that they were ‘Quite Often’ (3) or ‘Nearly Always’ (4) impeded by students giving up when work got difficult, reported very similar levels of mathematical knowledge and pedagogical confidence as those who selected ‘Hardly Ever’ (1) or ‘Now and Again’ (2) to C4.e, hence the green and blue lines remain relatively horizontal. However, in both graphs, the groups of teachers who reported ‘Quite Often’ (3) and ‘Nearly Always’ (4) being stopped from teaching as well as they wanted to, reported much lower confidence in teaching unmotivated students than their colleagues who only felt pedagogically impeded ‘Now and Again’ (1) or ‘Hardly Ever’ (1), as seen by the falling brown line. In both cases of C4.e and C4.f these differences were statistically significant ($p<0.01$ and $p<0.05$ respectively), suggesting these responses come from two distinct subsets of teachers in terms of their attitudes toward students.

Further analysis revealed another important feature of these data. While the graphs above plotted the mean confidence and knowledge levels, histograms showing the detailed frequency of responses reveal that the teachers who reported struggling the most with students giving up had almost exclusively reported higher levels of mathematical knowledge and confidence in teaching mathematics.

Figure 6.4 shows this somewhat counter-intuitive result more clearly. Each panel is a histogram of the frequency of responses to question B1 relating to mathematical content knowledge for each of the four groups of teachers identified earlier, that is, those who selected 1, 2, 3, or 4 on Question C4.e. What is revealed here is that those teachers reporting the lowest levels of mathematical knowledge felt least pedagogically compromised by students giving up. On the other hand, those teachers who felt most unable to teach well due to students giving up typically reported high levels of mathematical knowledge.

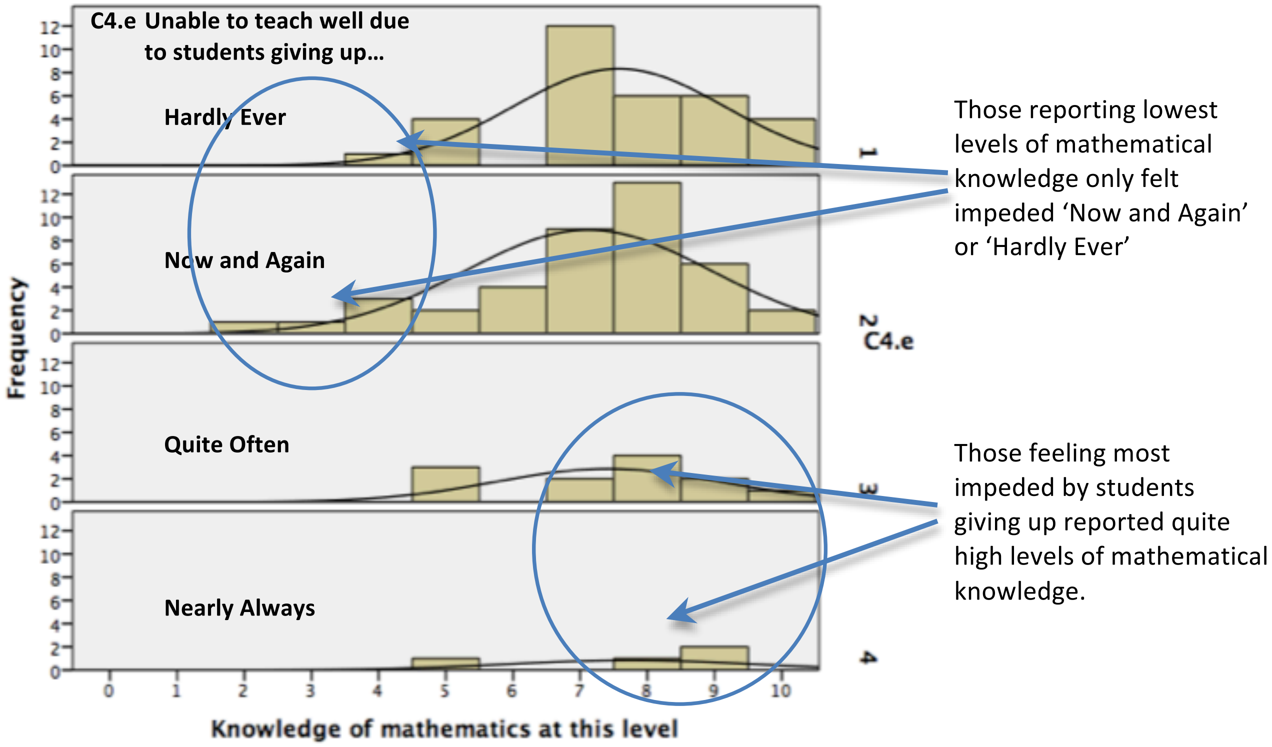


Figure 6.4 Histogram of responses to question B1 grouped by responses to question C4.e.

Obviously there were many teachers who reported high levels of mathematics knowledge who felt that students giving up 'Hardly Ever' stopped them from teaching well, or else only 'Now and Again', as can be seen in the top two histogram panels. But there is a distinct group who report high mathematics knowledge who felt impeded by students giving up 'Quite Often' or 'Nearly Always', as seen in the bottom two panels.

A similar pattern is evident for Question B2 relating to confidence in teaching mathematics. Here too those reporting the lowest levels of confidence only felt restricted in their teaching 'Now and Again' or 'Hardly Ever' while the confidence levels of those feeling restricted 'Quite Often' or 'Nearly Always' is significantly, and nearly universally, high (see Figure 6.5).

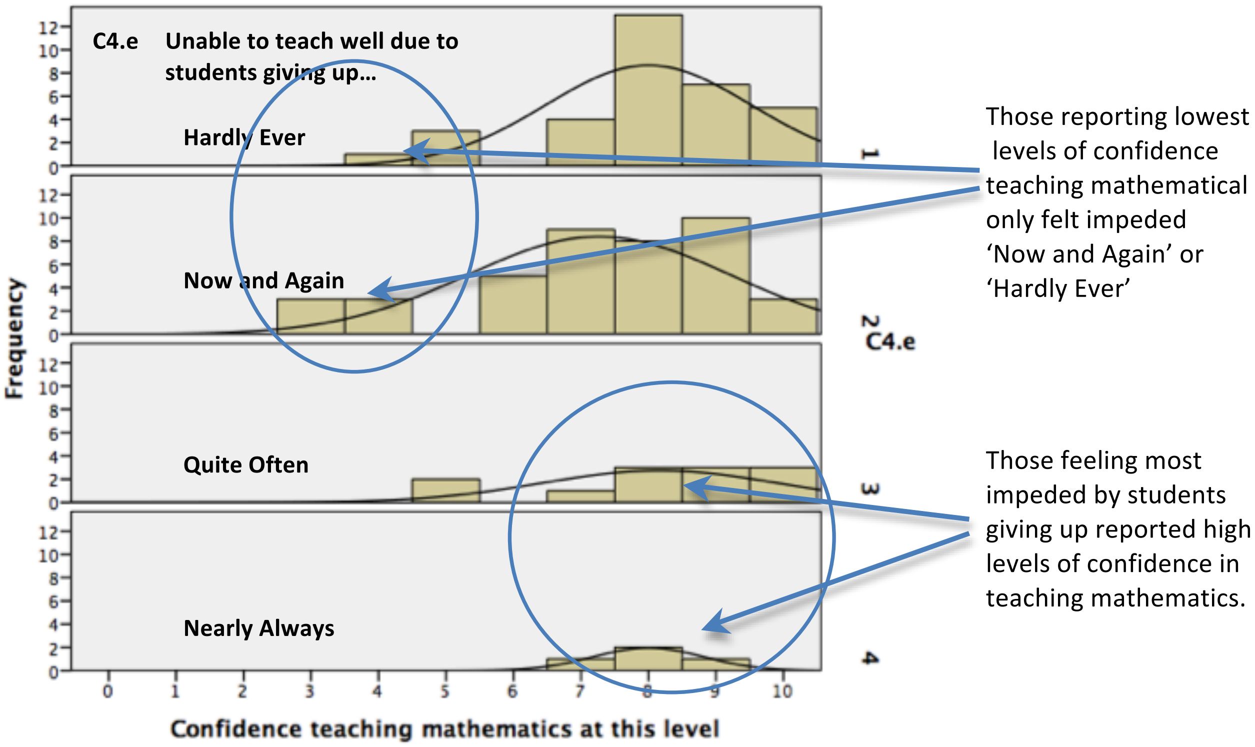


Figure 6.5 Histogram of responses to question B2 grouped by responses to question C4.e.

It would appear from these data that there is a subset of teachers who report high mathematical content knowledge and high confidence in teaching mathematics who view their students as failing to persist with difficult work and stopping them from doing a good job of teaching mathematics. This is in stark contrast with virtually all of the teachers who reported low knowledge and confidence who only felt impeded by students less often. This could indicate that less confident/knowledgeable teachers report being less restricted in their teaching by students because they are already restricted by their lack of SCK and confidence. However, Question C4 asks teachers to respond in relative terms, that is, how often their teaching is impeded relative to how they normally teach. Thus it seems that the majority of those most negatively impacted on by their students are those who reported high levels of mathematics knowledge and confidence.

This conclusion is supported by other survey data that suggest this subset of teachers appear to hold negative views about their students generally. This is confirmed by the statistically significant higher rates at which they recorded negative characteristics of their students, and statistically significant lower rates at which they attributed positive characteristics to their students in Question D1 of the

TTML survey. In other words, this subset of teachers seem to be unsympathetic towards their students in general when compared to other teachers, seeing greater levels of negative features, and lower levels of positive features.

Question D1 asked teachers to estimate the portion of their students who could be described by 17 different descriptors. Figure 6.6 shows this question with items considered to be positive descriptors of students are labelled with a hash (#) while items considered to be negative have been labelled with a caret (^).

D1. In your experience, what percentage of your mathematics students could be described as the following? *(each line is independent of the others and don't need to add to 100%)*

%

a. They seek success but only on tasks with which they are familiar ^ *
b. They associate getting smarter with trying harder #
c. They avoid or give up quickly on challenging tasks ^ ***
d. They discourage each other from trying too hard or appearing to be too smart ^ **
e. They connect effort with success and take pride in successful effort #
f. When experiencing difficulties, they seem to lose confidence in themselves ^ **
g. They seem to believe they are as intelligent now as they will ever get ^ ***
h. They remain focused on learning skills even when challenged # **
i. They are self motivated to learn # **
j. They try to do their best at mathematics # **
k. They plan out how they will tackle maths problems #
l. They connect trying hard now to increasing their opportunities in the future # *
m. They learn from their mistakes #
n. They contribute to class discussions # **
o. They listen when they should be listening # *
p. They prefer mathematics to be realistic
q. They always, or nearly always do their homework # ***

Figure 6.6 Question D1 from TTML survey. # positive ^ negative * $p<0.05$ ** $p<0.01$ ***$p<0.001$.

Teachers' responses to each of these questions were grouped in a similar way to those above, that is by the same teachers' responses to Question C4.e relating to being unable to teach well because of students giving up when tasks get difficult. Those items in Figure 6.6 marked with an asterisk had statistically significant differences between the mean responses of the teachers grouped in this way. For instance, there were statistically significant differences ($p<0.001$) between the four groups of teachers based on their responses to C4.e ('Hardly Ever', 'Now and Again', 'Quite Often', 'Nearly Always') and how each of these groups responded to D1.c ('They avoid or give up quickly on challenging tasks').

These results are illustrated graphically below where the same four groups based on responses to C4.e are compared. Figure 6.7 illustrates the pattern where negative items (D1.a, c, d, f, and g) trend upwards across the groups (representing increased prevalence) showing higher rates of negative attribution of student characteristics to those who felt that students gave up as the work got harder 'Quite Often' and 'Nearly Always'.

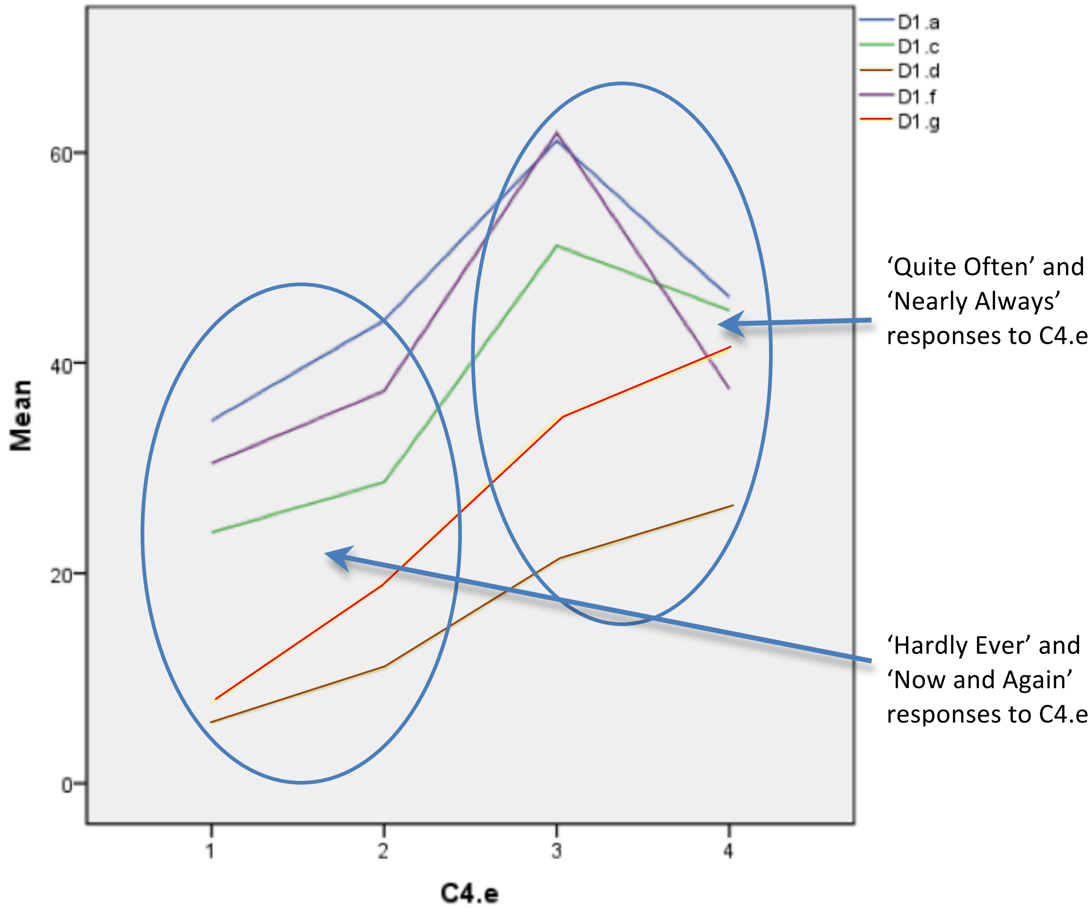


Figure 6.7 Graph of mean responses to negative descriptor Questions D1.a, D1.c, D1.d, D1.f, and D1.g grouped by responses to question C4.e.

There are noticeable spikes for the third group in terms of their responses to D1.a and D1.f compared to the other three groups, but nevertheless the third and fourth groups ('Quite Often' and 'Nearly Always') trend upwards on most of these negative attributions.

Figure 6.8 illustrates the downward trend across the four groups for the reported prevalence of positive items describing students (D1.h, i, j, l, m, n, o, and q). Note that once again the connecting lines are purely visual aids and do not represent intermediate values.

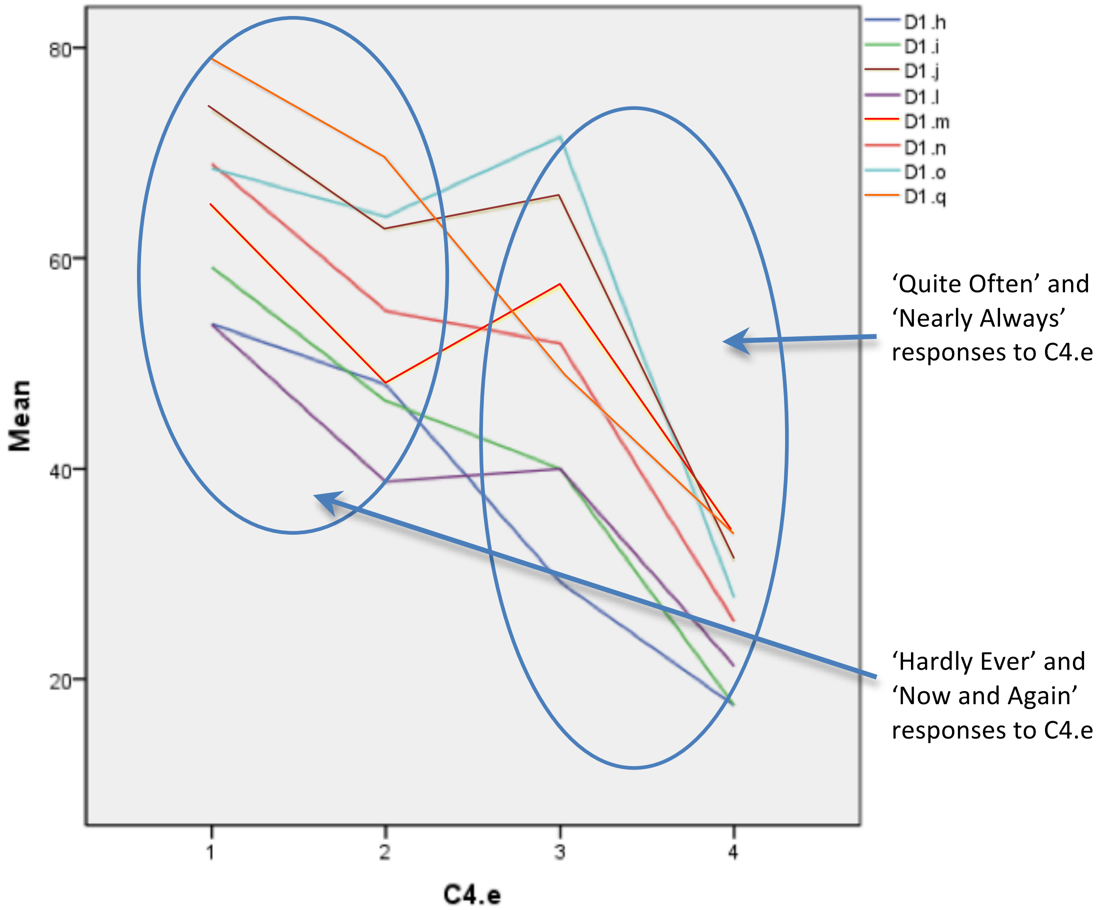


Figure 6.8 Graph of mean responses to positive descriptor questions D1.h, D1.i, D1.j, D1.l, D1.m, D1.n, D1.o, and D1.q grouped by responses to question C4.e grouped by responses to question C4.e.

Again there are a number of spikes in this graph, notably for D1.j, l, m, and o which, because these are positive attributions, reverse the trends for some of these questions, and point to some potential anomalies in the data. For instance D1.o asks teachers to nominate the percentage of students who listen when they should be listening, yet the group who 'Quite Often' feel that they cannot teach as well as they wish to because their students give up have indicated a higher percentage of students listening when they are supposed to than any other group. Of course students who give up do not necessarily not listen appropriately, so it is not strictly contradictory, but perhaps somewhat counterintuitive. However, overall the majority of positive attributions fall across the groups.

These two graphs demonstrate the statistically significant differences in average responses to the D1 items by the different groups of teachers based on their responses to C4.e (inability to teach due to students giving up when work gets difficult). Once again there are clear trends that those who selected 'Quite Often'

(3) and 'Nearly Always' (4) on C4.e perceived their classes as having a greater number of students exhibiting negative characteristics, and fewer students exhibiting positive characteristics, than those teachers who selected 'Now and Again' (1) or 'Hardly Ever' (2) on C4.e.

It would appear that this subset of confident knowledgeable teachers view their students in a more negative or pessimistic light compared to their colleagues who perceive their students as being more persistent. These pessimistic teachers make up 17% of the overall cohort who completed the TTML survey, and taking into account the notion of self-fulfilling prophesy, they might also be considered less skilled by virtue of their students being at an educational disadvantage relative to their peers, despite their high levels of confidence and mathematical content knowledge. If this is a fair representation of the broader teacher population then there are significant equity implications if over one in six mathematics teachers view their students negatively and if holding such views can have a negative impact on how well their students learn mathematics. The next section explores the mechanism of self-fulfilling prophesy in greater detail.

6.2.1.3 Self-fulfilling prophesy and mathematical inequity

These data are significant because they are likely to have an impact on the way that teachers teach because of what is described as self-fulfilling prophesy. The following discussion draws heavily on a review of research on self-fulfilling prophesy by Brophy (1983). Essentially the notion of self-fulfilling prophesy is that for classes, groups or individuals, if teachers think the students are bright (independent of whether they are or not) the students learn better, and if teachers think that the students will experience difficulty then those students do so. This is particularly relevant when considering the identified subset of unsympathetic teachers who appear to hold negative thoughts about many, if not most, of their students.

Brophy (1983) posed a cyclic model that describes how this self-fulfilling prophecy might operate:

Step 1: Teachers form early differential expectations for their students.

Step 2: As a result, these teachers behave differently to different students and effectively communicate their expectations to their students through verbal and non-verbal cues. If such treatment of the students is consistent, and if the students do not resist, it will have an effect on their self-concept, achievement, motivation, aspirations and classroom conduct.

Step 3: These triggered responses of the students actively reinforce the teacher's original expectations, and ultimately there will be a difference in student achievement and outcomes.

Despite some reservations about the reality of this phenomenon, a number of studies have found that teachers do respond differently to different students. Brophy (1983) identified research that reported that teachers do sometimes:

- wait less time for low achieving students to answer;
- give low students the answer or call on someone else rather than waiting;
- use inappropriate reinforcements;
- criticise low achieving students more for failure and praise them less frequently;
- do not give public feedback on public responses of low achieving students;
- call on them less to respond;
- demand less from the lows; and
- have less friendly verbal and non-verbal contact.

Brophy (1983) claimed that high expectation students raise their hands to volunteer more often, initiate more interactions, give correct answers more often, have fewer problems in reading, are criticised for misbehaviour less and receive more praise. Overall it appears that high achieving students tended to be more attentive, more likely to volunteer information, have an expectation of success and receive more praise and less criticism and produce positive responses from teachers.

One of the explanations put forward related to what Brophy called the teachers' need for control. For example, when dealing with high expectation students, it is suggested that teachers feel more able to predict student behaviour when interacting both privately and publicly, and whether or not the teacher or the student initiates the interaction.

On the other hand, if teachers are worried about control they are likely to avoid public interactions with low expectation students, especially ones the students have initiated. In other words, in group situations teachers may call on low expectation students less, and ignore or discount their attempts to initiate questions. Teachers' feedback to low expectation students may be a product of a desire to terminate an interaction rather than continue it. So to some extent this self-fulfilling prophecy may be related to survival in the classroom. However, it is interesting that the subset of unsympathetic teachers here report such high levels of pedagogical confidence and mathematical knowledge, yet hold what appear to be low expectations of their students.

Another of the explanations is related to attribution. For example, a teacher who attributes to themselves a student's failure is possibly likely to give further explanations and to seek other ways of explaining the difficult idea. If however the teacher attributes the failure to a student's lack of ability, they may give up and move the student on to some other simpler task. However, again, these confident knowledgeable teachers are feeling constrained from being able to teach properly due to their students giving up easily, and have expressed difficulty in dealing with unmotivated students, whereas their less knowledgeable counterparts report no such difficulty.

Nevertheless, while there may be some doubts about the impact of self-fulfilling prophesy, there remain two groups of teachers who are plausibly disadvantaging their students. Combining those teachers who reported low levels of mathematical content knowledge and pedagogical confidence with the confident knowledgeable, yet unsympathetic teachers in the TTML sample gives us a total of 35% of teachers who might be contributing to relative student disadvantage. In itself this is problematic, but there is a potential inequity amplifier effect explored in 6.2.2 below.

6.2.2 A longitudinal perspective and random inequity

While there is an obvious preference in the research community for mathematics teachers to feel confident in possessing the requisite skills to teach mathematics satisfactorily, there is a broader issue relating to teachers being adequately skilled from the students' perspective. As discussed above, assuming that teachers can (and do) accurately gauge their pedagogical skills and mathematics knowledge, and further, that there is a connection between teachers' pedagogical skills, subject content knowledge, and student learning, then the students of teachers lacking confidence and mathematical content knowledge, and students whose teachers are unsympathetic to them, could be said to be disadvantaged relative to their peers who have confident, knowledgeable, and sympathetic mathematics teachers. It might be said that such students experience a *sub-optimal year of mathematics* due to being taught by teachers from these different groups. For instance, teachers from one group may provide inadequate explanations, while teachers from the other group may provide good explanations but in a way that alienates students.

Whilst it seems reasonable to expect any misunderstandings or mislearnings arising from one sub-optimal year to be corrected in subsequent years by more confident, knowledgeable, and sympathetic teachers, there remains the possibility that some of these students could experience another sub-optimal year the following year, and even in the year after that. Given the largely sequential nature of the mathematics curriculum, recovery from having a series of sub-optimal mathematics years might be difficult for many students, and such experiences may well result in a permanent loss of confidence and mathematical disengagement for these students.

While the chances of having three sub-optimal years in a row are remote, there is a variety of possible combinations throughout the compulsory years of schooling that might reasonably be expected to result in randomly inequitable results. Three broad issue types have been identified where a student might reasonably be described as having been severely disadvantaged through no fault of their own. The three scenario types are:

- Issue Type I represents students who have experienced five or more sub-optimal years of mathematics from Prep to Year 10;
- Issue Type II represents combinations where a student experiences sub-optimal mathematics years in four out of any contiguous seven year period; and,
- Issue Type III represents scenarios wherein three out of any contiguous four year period are sub-optimal.

It is assumed that these three scenario types would have lasting negative effects on a student's ability to learn mathematics effectively due to a chronic prevalence of sub-optimal years over a long period of time (Issue Types I & II), or an acute cluster of sub-optimal years in a relatively short space of time (Issue Type III).

Table 6.1 attempts to give some sense of the scale of this problem. It gives a sample of the scenarios students might experience out of the 2048 possible combinations where students could be expected to experience sub-optimal years during their compulsory years of schooling. In the table a 1 represents a sub-optimal year, while 0 represents a year with a confident, knowledgeable, and sympathetic mathematics teacher.

Table 6.1 Sample of possible scenarios where a student might experience sub-optimal years of mathematics from Prep - Year 10.

P	1	2	3	4	5	6	7	8	9	10	Number of sub-optimal Years	Issue Type	Pr(35%)
0	0	0	0	0	0	0	0	0	0	0	0	-	0.00875
0	0	0	0	0	0	0	0	0	0	1	1	-	0.00471
0	0	0	0	0	0	0	0	0	1	0	1	-	0.00471
0	0	0	0	0	0	0	0	0	1	1	2	-	0.00254
0	0	0	0	0	0	0	0	1	0	0	1	-	0.00471
0	0	0	0	0	0	0	0	1	0	1	2	-	0.00254
0	0	0	0	0	0	0	0	1	1	0	2	-	0.00254
0	0	0	0	0	0	0	0	1	1	1	3	III	0.00137
0	0	0	0	0	0	0	1	0	0	0	1	-	0.00471
0	0	0	0	0	0	0	1	0	1	1	3	III	0.00137
0	0	0	0	0	0	0	1	1	0	0	2	-	0.00254
0	0	0	0	0	0	0	1	1	0	1	3	III	0.00137
0	0	0	0	0	0	0	1	1	1	0	3	III	0.00137
0	0	0	0	0	0	0	1	1	1	1	4	II	0.00074
0	0	0	0	0	0	1	1	1	1	1	5	I	0.00040
1	0	0	0	1	0	0	0	0	1	1	4	-	0.00074
1	0	0	0	1	0	1	0	0	1	1	5	I	0.00040
1	0	0	1	0	1	1	0	0	0	0	4	II	0.00074
1	0	1	0	1	1	1	1	1	1	1	9	I	0.00003
1	0	1	1	0	0	0	0	0	0	0	3	III	0.00137
1	0	1	1	0	0	0	0	0	0	1	4	III	0.00074

The ‘Issue Type’ column designates which of the three problematic scenarios is represented by that row while the ‘Pr(35%)’ column shows what the probability of each combination has of occurring assuming that 35% of teachers might provide sub-optimal years of mathematics for students, based on the figures discussed in Section 6.2 above regarding mathematics teachers lacking confidence, content knowledge, and/or being unsympathetic toward their students. For instance, assuming this 35% figure to be accurate, the table shows that the probability of a student never having a sub-optimal year of mathematics from Prep to Year 10 would be approximately 0.00875. Alternatively this could be expressed as a percentage of students likely to be affected, that is less than 1% (0.88%) of students could expect to never have a sub-optimal year of mathematics in their P-10 years of schooling. Conversely, combining the probabilities of all three Issue Types (I, II, and III) suggests that 49.5% of students could be expected to be randomly disadvantaged as a result of having experienced five or more sub-optimal mathematics years, or four sub-optimal years out of seven, or having had three sub-optimal years within any four year period.

As mentioned above, this 49.5% of students who could be expected to be randomly disadvantaged is predicated on the assumption that 35% of teachers result in sub-optimal mathematics years for students. Variations in this number directly impact on the calculated number of randomly disadvantaged students, as shown in the following table and graph (Figure 6.9) which depicts the relationship between the proportion of sub-optimal mathematics teachers and the proportion of students that might reasonably be expected to be severely disadvantaged.

% sub-optimal Teachers	% Randomly disadvantaged Students
0%	0%
3%	0.07%
5%	0.295%
10%	2.188%
15%	6.728%
20%	14.268%
25%	24.498%
30%	36.595%
35%	49.458%
40%	61.951%
45%	73.119%
50%	82.324%
55%	89.000%
60%	94.000%
65%	97.000%
70%	99.000%
75%	99.900%
80%	99.990%
85%	99.999%
90%	100.000%
95%	100.000%
100%	100.000%

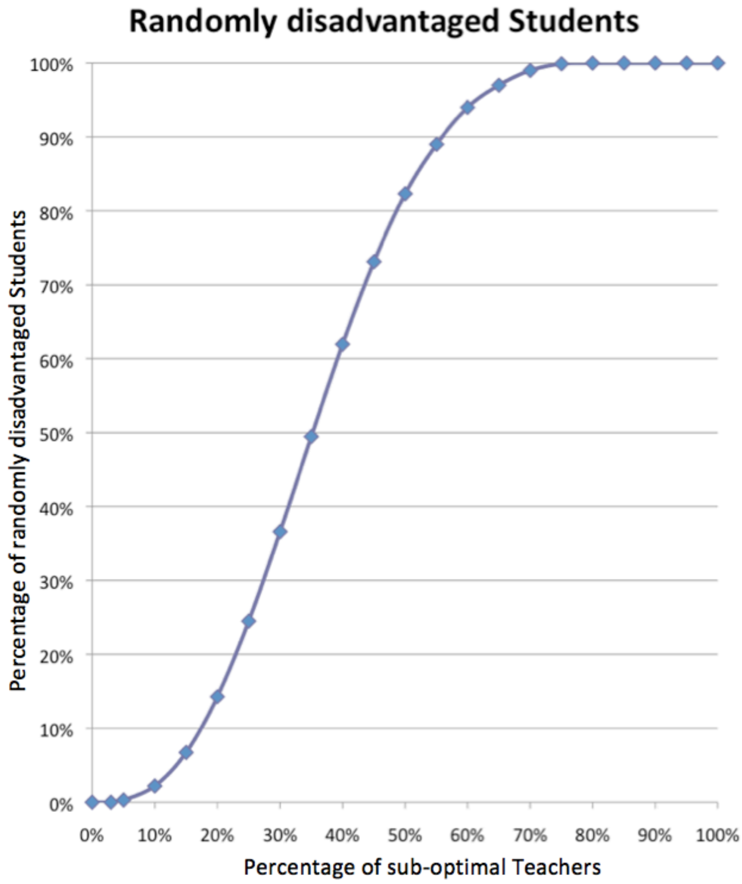


Figure 6.9 Table and graph showing the relationship between percentage of sub-optimal mathematics teachers and randomly disadvantaged students.

It seems that the process of random inequity dramatically amplifies the negative impact of even modest levels of sub-optimal teaching within the schooling system.

Because the curve in Figure 6.9 has such a steep gradient, a large school of 1,000 students could only expect to reduce the impact of random inequity on less than one student if 3% or fewer of their mathematics teachers were sub-optimal.

At the other end of the spectrum, if just over half (55%) of all mathematics teachers are less effective, then nearly all students are likely to be randomly disadvantaged (89%). Ironically it may be easier to remedy random inequity by reducing the number of skilled mathematics teachers so that all students are equally disadvantaged, since even relatively low levels of less skilled teachers, say 5%, could still be expected to disadvantage at least one student at a small school of 2-300 students. Even this low rate of under performing teachers would still translate to thousands of students being disadvantaged across Victoria, and over ten thousand students across Australia.

This poses a serious problem for a meritocratic schooling system that places high value on mathematics, since without a near perfect teacher workforce, a large portion of students are likely to be disadvantaged relative to their peers.

6.2.3 Ameliorating effects

Fortunately the categorisation of teachers as either sub-optimally or adequately skilled is probably too simplistic for this analysis to be fully borne out in reality. While some teachers might report a global lack confidence and knowledge in mathematics, it is far more likely that they lack confidence and knowledge in only certain areas of mathematics. This would tend to reduce the impact on students given that two or more sub-optimal teachers would be likely to have complementary skill sets rather than mutually reinforcing/undermining ones.

It is also possible that whilst teachers report feeling unconfident and unknowledgeable with mathematics, this is only relative to other people or colleagues they know who appear (or in fact may be) very confident – perhaps even over-confident – and knowledgeable in mathematics and mathematical pedagogy. Despite feeling a lack of confidence and knowledge, these teachers might still be more than adequate mathematics teachers as far as the needs of their students are concerned.

There are also potentially ameliorating factors associated with particular schools and school cultures. In schools where students are attentive and well behaved, even students who have been disadvantaged may benefit from supportive peers who can help 'fill' any gaps for them, as well as teachers having more time to assist them when the class has a minimal number of behavioural issues.

However, the converse may be true for schools where behavioural issues are more dominant and where skilled teachers struggle to teach as well as they are otherwise able. It is also possible that the impact on students have been underestimated in this modelling in terms of interactions across sequential years. For instance, if a student learnt a concept or technique correctly one year, were mistaught the same information in the next sub-optimal year, only to be corrected again the following year by a third teacher, this may be sufficient to erode a student's confidence in themselves or in whether any of their teachers really knows what is going on in mathematics. Such a crisis of confidence could be the result of encountering a single sub-optimal teacher let alone three out of four, or four out of seven. So while some of the assumptions underlying the analysis may overstate the case, it is possible that other assumptions understate it, and further dedicated research would be required to make any robust claims either way.

The other important factor is the prevalence of sub-optimal teachers, and while the current study has produced data that seem to shed some light on this, further research would be needed to arrive at a confident estimate of the real figure, and the potential scale of impact suggests that this is probably a problem worthy of further investigation to identify more accurately the magnitude of ameliorating effects, as well as which scenarios best represent student disadvantage.

Nevertheless, because of the dramatic amplifying effect of random inequity, even small fluctuations in the proportion of sub-optimal teaching within the schooling system has the potential to have considerable impact on the relative disadvantage experienced by students excluding, or in addition to, any other inequitable pressures they might be experiencing by virtue of gender, race, geography, or socioeconomic status. In fact, if certain teachers contribute to these other forms of inequity – perhaps through mechanisms like self-fulfilling prophesy – then this could further add to the number of sub-optimal teachers for certain groups. For instance, if an optimal mathematics teacher in terms of confidence, knowledge, and sympathetic attitude towards students happened to have negative opinions of students from particular ethnic groups, they might increase the pool of sub-optimal teachers for students from minority backgrounds to experience. In this way while the underlying percentage of sub-optimal mathematics teachers might sit at 35% for the general student population, for students from ethnically different backgrounds this sub-optimal percentage might be 40% or more. Thus random inequity could well interact with other forms of inequity in different ways for students sharing different backgrounds or characteristics, demonstrating that as a conjecture it is at least logically consistent with previously identified forms of inequity, and illustrates how exposure to sub-optimal mathematical experiences in the long term could bring about widespread disengagement of students from mathematics.

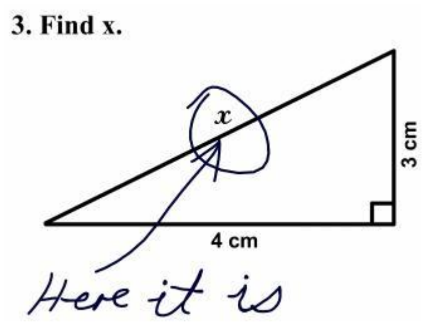
6.3 *Summary of the chapter*

Equity has long been a concern within education and mathematics education in particular. While traditional concerns with equity relate to identifiable groups within the student populace, it seems that the diversity of competence within the mathematics teacher workforce has the potential to disenfranchise and disadvantage a significant proportion of students based on purely random processes. Based on the initial TTML survey 35% of teachers are arguably less skilled at teaching mathematics than their colleagues, resulting in 50% of students potentially falling victim to random inequity.

Such a figure is concerning, and given the importance placed on mathematics within our society the results could be deleterious for a substantial number of students through no fault of their own, and there is likely a compounding effect between random inequity and other kinds of inequity. A problem of this scale would be difficult, if not impossible to rectify in a short time frame. This raises concerns about the emphasis placed on mathematics in society, the negative effects associated with mathematical failure, and the anti-meritocratic role mathematics might play as a result of such inequity. These issues are explored further in the next chapter.

CHAPTER 7

School mathematics and its place in society



The commonplace mathematics question, ‘find x’, has a distinct meaning that renders the answer given above amusing. While this answer may have been given in jest, it could also be seen as the best effort of a student attempting to make sense of a question with few connections to their *real life* experiences. In a life devoid of an understanding of formal algebra, ‘find x’ is reasonably read in the same way as ‘where's Wally’. It seems that many people’s lives part company with more sophisticated mathematics after leaving school, and that while they would likely recognise the categorical error in the above answer, they probably could not provide the correct answer. Such disconnects between people’s lives and school mathematics may be common as well. For instance we have already seen that many mathematics teachers have reported symptoms consistent with maths anxiety; that the expectations of mathematics education researchers is sometimes at odds with the realities of the classroom and the abilities of competent, or good-enough, teachers; students may be alienated from mathematics by teachers who are unsympathetic toward them or hold low expectations of them; students may be deprived of quality mathematics instruction by teachers who lack confidence and appropriate knowledge. All of these illustrate a gap between people’s realities and what is expected of them within the context of school mathematics.

Society privileges mathematics and has high expectations of what students should learn, and even though school mathematics is often perceived by students as being of no direct relevance to their current lives, they still hold beliefs (and hopes) that it will be of some use to them later in life (Toomey & O'Donovan, 1997). Even though mathematics is held in near universal high regard, its role in education remains contested. Having come a long way from the original aims of the thesis of attempting to help teachers to generate their own data to reflect upon, this chapter explores connections between student interest in mathematics, the interests of other social groups in the teaching of mathematics, and how informative these divergent perspectives are in deciding what the role of school mathematics should be. It may be that rather than being part of the solution to helping people succeed in life, school mathematics may be inadvertently harming them.

7.1 *Mathematics and student interests*

Many researchers have identified a crisis in mathematics education. Low student engagement, reduced enrolments into related tertiary courses, and the subsequent shortage of suitably skilled workers have all been flagged as causes for concern as industries transition into the knowledge economy (Drucker, 1993). Students who find mathematics at school hard and boring, get poor grades in mathematics, or dislike their teachers, tend to reject mathematics outright – or else they enrol in mathematics but remain uninterested (Department of Education, Science and Training, 2006). Such attitudes and behaviours may account for the 20% drop in enrolments in high level mathematics across Australia from 1990 to 1999 along with the corresponding 92% increase of enrolments in lower level mathematics for the same time period (Dekkers & Malone, 2000) and the continued decrease in intermediate level enrolments from 2000 to 2004 (Forgasz, 2005). It may also be relevant that the attitudes of the current generation of students (Gen Y) have been identified as being a form of pragmatic materialism in that, whilst they are largely interested in financial security and happy family lives, they see the pursuit of specialised tertiary education as inflexible and not providing the adaptability that they believe they will need in a world largely devoid of job security (Saulwick Muller Social Research, 2006).

This situation is exacerbated by the fact that much secondary level mathematics lacks any obvious day-to-day applicability, with the ubiquitous "what use is this?" question remaining essentially unanswered for students, and so failing to convey to students an appreciation of the value and utility of mathematics. It is perhaps unsurprising that if looked at as a product available for students to ‘purchase’ (enrol in) post-compulsory mathematics is not something that many Gen Y ‘consumers’ want to buy. Either the link between mathematical success and career options is not clear enough for these students to see it as a good investment, or they see mathematics as being so abhorrent or dull that they have no interest in pursuing careers that require it.

For some time mathematics has been widely regarded as holding a privileged position within school curriculum and acting as a form of “gatekeeper to participation in the decision making processes in society” and as a means of deciding who in society ‘can’ and who ‘cannot’ (Volmink 1994, p.51). When viewed from the students’ perspective it is more a matter of which subjects are worthwhile and which are not. Does mathematics offer them something of value, something that will lead them to a career they wish to pursue? It seems reasonable to assume that if a student has been disenfranchised from mathematics through one form of inequity or another, that their aspirations will have been modified accordingly. Careers requiring mathematics may lose the appeal they once had, or simply become seen as impossible dreams. In this way systemic inequities within mathematics may create a process of self censorship, not acting as a gateway per se, but rather as a way of moderating students’ ambitions so that they spontaneously opt out of pursuing mathematics based careers. In this way such students may still be perceived as those who ‘cannot’, but their self narrative may be more constructively couched in terms of ‘not wanting to’.

It is important to note that there are at least two possible influences on students not wanting to pursue mathematics based subjects and/or careers. The first source is the one just alluded to, that they have been alienated from mathematics through some mechanism of inequity leading to self exclusion. The second source of ‘not wanting to’ may simply arise from a genuine lack of interest in mathematics – they may simply find the world of mathematics uninteresting in the same way that many people find Baroque poetry or Latin uninteresting. This notion of students ‘not wanting to’ seems to underlie Fennema’s (2000) personal doubts about the value of attempting to arrive at equal achievement in mathematics for girls. In contrast to her earlier views (e.g., Fennema, 1990) she argues that girls may, on the whole, tend to be less interested in mathematics than boys because they are more interested in other things.

If this is true, it is implicit that within this range of interests in mathematics some girls will be more interested in mathematics than many boys, and some boys will be less interested in mathematics than most girls, even though on average, girls are less interested in mathematics than boys. However, in shifting the focus onto interest rather than ability, the issue becomes one of whether students are entitled to lack interest in mathematics, and if they are, should they be penalised for being so disposed? After all, if Baroque poetry was a mandatory part of the curriculum then similar patterns of engagement might be observed. In fact there was a time when Latin was not only a mandatory part of the curriculum, but also considered to be the core of the curriculum (Kaulfers, 1949). If declining student interest is taken as a significant factor in deciding matters of curriculum, it is also important to examine other factors and perspectives that should be taken into account. Essentially this entails examining the philosophical underpinnings and justification for school mathematics and asking along with Fennema (2000), "is mathematics really necessary for a life of value in the 21st century?"

7.2 *Why teach mathematics?*

Given the ubiquity of mathematics in school curricula and the general importance attributed to numeracy, it appears almost naive to ask why we should teach mathematics. It is typically considered obvious that mathematics should be taught, and a variety of reasons are often put forward as to why mathematics ought to feature prominently in what schools do, ranging from sharpening students' minds through to catering for the needs of the future economy. It is not always possible to reconcile the diversity of justifications offered as they often represent disparate views of particular interest groups within society. Ernest (1986) identified three interest groups as having particular views about school mathematics: educators; mathematicians; and representatives of both industry and society. He subsequently refined these categories into five social groupings viz. Industrial Trainers, Technological Pragmatists, Old Humanists, Progressive Educators, and Public Educators (Ernest, 1991). The following provides an overview of the motivations and underlying ideologies attributed to each of these groups.

7.2.1 Industrial trainers

Industrial Trainers represent those who have a hierarchical world view of society and value a ‘back to basics’ view of mathematics where teachers transmit numeracy and mathematical facts and processes to students via an authoritarian emphasis on drills, processes, and mental calculations. This group is often associated with the political right-wing and moral dualism in the sense that they operate in terms of ‘right and wrong’ in the context of an authoritarian paternalism. Ernest (1991) identifies the movement as being epitomised by the 1980s British Prime Minister Margaret Thatcher and her advocacy of the values of hard work, self-help, fiscal prudence, the immorality of extravagance, and placing duty ahead of pleasure. He further connects the underlying ideology of Industrial Trainers to the Calvinistic and Methodist traditions wherein children are seen as ‘fallen angels’ who are sinful by nature and need to be kept constantly busy in keeping with the Puritan notion of ‘idle hands are the Devil’s workshop’. True facts and correct skills are considered to be the extent of useful knowledge which children should learn from the recognised authorities and experts. Their overarching educational aims are twofold. On the one hand the masses should develop mastery of basic skills and be trained in obedience and servitude as readiness for the world of work befitting their low social status. On the other hand, those from the upper classes should develop mastery of a broader range of knowledge and be trained and prepared for their future leadership roles. As such, school mathematics should endeavour to produce functionally numerate and obedient students through the application of hard work and practice, with competition as the best source of motivation and streaming by ability as the most appropriate way to allow students to progress at different rates in readiness for occupying their appropriate positions in the world. The way this and the following four sections connects to the analysis is elaborated on in Section 7.2.6.

7.2.2 Technological pragmatists

Technological Pragmatists represent those with a meritocratic social world view who value practical, industry-centric, functional mathematics where teachers develop students’ skills in preparation for the world of work. Whilst sharing certain aspects of the Industrial Trainers view of the utility of mathematics, the

Technological Pragmatists adopt a more pragmatic approach and are more concerned with progressing their industrial interests through technological advances. According to Ernest (1991) the main ideological features of this group is an unreflective acceptance of existing social structures combined with an emphasis on action and practical outcomes as the touchstone of judging intellectual and moral issues. While there may be diverse opinions amongst technical experts, the 'proof of the pudding is in the eating' in that judgments are based on the grounds of utility, convenience, and self interest. So while they aim for students to be equipped with the kinds of mathematical skills and knowledge that will be needed for employment and the certification of student attainments in this regard, they also seek to further technological advances in order to improve their own economic prospects.

7.2.3 Old humanists

Old Humanists have an elitist sense of social order and value a mathematics-centric curriculum where teachers transmit an understanding and application of classical mathematical knowledge to students. Like the Industrial Trainers they accept that only a minority will achieve a proper liberal education and appreciation for 'true' culture, but share with the Technological Pragmatists a certain meritocratic mindset in the sense that those who can succeed should succeed, and that those who cannot succeed will nevertheless gain something from the experience of having tried. As such they believe there are intrinsic aesthetic benefits to teaching pure mathematics and emphasising its structure, concepts, rigour, and intellectual beauty.

7.2.4 Progressive educators

Progressive Educators support a welfare orientated society and view mathematics from a student-centred perspective as a rich environment of knowledge where teachers lead students in a creative exploration of mathematical ideas. To these ends they focus on providing a structured learning environment, fostering children's active exploration of mathematics, and shielding them from negative experiences to preserve positive feelings, motivation, and attitudes toward mathematics. The teachers' responsibility is first and foremost located in benefiting the learner without regard for the social utility of what is taught.

7.2.5 Public educators

Public Educators see society as being inequitably organised and in need of reform. They view mathematics as a tool that teachers can use to explore relevant social issues with students and thereby help them to develop critical awareness and learn to exercise democratic citizenship. They view mathematics as constructed knowledge, and therefore fallible, and aim to empower students to 'own' mathematics as one way of seeing and thinking about the world, helping them to confidently pose and solve problems within their own social and political contexts. Ultimately mathematics should contribute to the furtherance of equity and social justice.

7.2.6 Interplay between each groups' views and motivations

The following summary table of these categories (Table 7.1), excluding some additional descriptors, is derived from Ernest (2007).

Table 7.1 Ernest's (2007, p.6) five social interest groups and their views of mathematics.

Interest Group	Industrial Trainers	Technological Pragmatists	Old Humanist Mathematicians	Progressive Educators	Public Educators
Social Location	Radical 'New Right' conservative politicians and petty bourgeois	Meritocratic industry-centred industrialists, bureaucrats, industrial mathematicians	Conservative mathematicians preserving rigour of proof and purity of mathematics	Professionals, liberal educators, welfare state supporters	Democratic socialists and radical reformers concerned with social justice and inequality
Mathematical Aims	Back-to-basics numeracy and social training in obedience (authoritarian)	Useful mathematics to appropriate level and certification (industry-centred)	Transmit body of pure mathematical knowledge (maths-centred)	Creativity, self-realisation through mathematics (child-centred)	Critical awareness and democratic citizenship via mathematics
Views of Mathematics	Absolutist set of decontextualised but utilitarian truths and rules	Unquestioned absolutist body of applicable knowledge	Absolutist body of structured pure knowledge	Absolutist body of pure knowledge to be engaged with personally	Fallible knowledge socially constructed in diverse practices

The distinctions in this table are not rigid and there is ample scope for areas of overlap between many of them. There is also the suggestion of a loose spectrum as we move across the categories from left to right, moving closer to the classroom and further away from historical social traditions. Ernest (2007) acknowledges that his model is a "gross simplification" (p.7) and that it should not be taken too literally. For instance, he rejects that there is necessarily any logical connection between each interest group and their stated mathematical aims, but rather that there tends to be correspondence between them. That is, the aims attributed to each group can, more or less, be found historically to have been espoused by people who might readily be described by one or other of the identified social groupings. He also accepts that individual teachers have been found to hold complex combinations of these beliefs rather than fitting cleanly into any one category (Ernest & Greenland, 1990). So while the model has no real predictive power per se, it does serve as a way of conceiving of, and discussing, the various interest groups that come to bear on issues surrounding mathematics education.

It is interesting to note that by and large each group adopts the perspective of mathematics that they feel would result in securing their own position in society, or creating future members of their own group. For instance, the Industrial Trainers endorse infusing students with self-discipline and obedience, knowing both their own, and others, places in society – literally preserving the status quo. Technological Pragmatists promote a meritocratic, practical approach which rewards those who 'can', providing a pathway for practical pragmatists to rise to positions of power through further technological advances. The Old Humanists seek to imbue students with an appreciation of the beauty and Platonic purity of mathematical knowledge, thereby nurturing the next generation of Old Humanists who resonate with the aesthetical nature of mathematics – just as they themselves do. Progressive Educators value personal growth and liberal ideals, so endeavour to protect students from failure in order that they too can grow into adults who value and support the growth of others. Similarly, Public Educators aspire to a just society by reducing or eliminating inequity, and believe that the removal of barriers will allow every student the opportunity to become critical members of society who will, like them, strive to root out injustice wherever it is found.

Viewed in this way, each group has their own autobiographical trajectory that they followed themselves in relation to mathematics, and they seek to preserve this trajectory as a valid pathway for current and future students. In a nutshell, 'if it was good enough for me, it's good enough for you'. By considering the self-preservation aspects of their perspectives it is easier to see how, and why, each group's priorities might clash with the others. For instance, Industrial Trainers would be at odds with Public Educators because they each seek to actively quash the other's social goals – the Industrial Trainers wish to preserve existing social structures while the Public Educators wish to change them. Old Humanists would clash with Technological Pragmatists because the latter group do not value the mystery and magic of mathematics, they merely wish to use it as a tool to achieve wealth, while the Technological Pragmatists would see the Old Humanists as wasting time, energy, and money pursuing useless mathematical ideas instead of focussing on what has practical application in the real world. Even Progressive Educators and Public Educators would disagree about the nature of mathematics, the latter seeing it as socially constructed knowledge, the former as absolute knowledge that students will benefit from understanding. At base much of these disputes can be seen as efforts toward self-preservation in the face of opposing forces that would, given the chance, dominate and eliminate the opposing world views if they could.

Having said that, it is perhaps important to locate this thesis, within this model. I find myself spread across several, if not all of the five categories, depending upon whether I am considering social/political views, mathematical views, or philosophical views. I am inclined toward social justice and critical awareness of the world we are in, but am not unimpressed by the technological advances that have been possible through the application of mathematical and scientific ideas. I see value in child-centred personal growth approaches to education, yet acknowledge the importance of preparing students well for practical participation in society through gainful employment. I also acknowledge that traditions are to some extent important, in so far as they can help maintain a sane culture, and abate the chaos that would ensue in a state of constant reform and revolution. And I appreciate that there is something transcendent in the world of numbers that is mysterious and appears to connect us with a reality quite different from the physical one we are immersed in. So if I had to nominate the extent to which I subscribed to each group I would probably rank them in the order of Public Educator, Progressive Educator, Technological Pragmatist, Old Humanist, Industrial Trainer.

Setting aside the narcissistic elements of psychologically profiling oneself, this self-analysis helps to uncover two fundamental issues. First is that it raises the question of who should decide what happens with school mathematics. Second, it is clear that a person can be sympathetic toward all five groups depending on which aspect of reality is their focus at any given time. This suggests that each approach has an expertise that is particularly applicable to some areas and not to others. The next two sections explore these issues separately.

7.3 *Who should decide what happens with school mathematics?*

My particular set of dispositions do not uniquely qualify me to set the agenda for school mathematics, but then neither should any other set of dispositions necessarily be seen as uniquely qualified – regardless of any assertions they might make for themselves being so qualified. The recent (and ongoing) 'math wars' in the United States of America is a public battle between several of these groups contesting each other for the position of final arbiter of what school mathematics should be. University based mathematicians became heavily involved in the 1990s in attempting to influence the nature of school mathematics (Klein, 2003). The ensuing disputes resulted in a public letter published on the 18th of November 1999 in the Washington Post signed by 225 academic mathematicians criticising the proposed school mathematics reforms. This approach fairly clearly demonstrated a case of Old Humanists reacting to documents that did not epitomize their own perspective on mathematics. Progressive Educators responded with their own accusations such as:

> if research mathematicians would engage in 'civil, constructive' criticism rather than, more often than not, arrogant put-downs, the result of the Math Wars would not be an endless battle to the detriment of school mathematics education. (Ralston, 2004, p.410)
>
> just because mathematicians are good at mathematics, they [wrongly believe that they] should also be able to contribute to the effective presentation of elementary mathematics to an often unmotivated and unresponsive public. (Clemens, 1999, p.180)
>
> mathematicians have…largely failed to help teachers learn the mathematics they need in pre-service. (Roitman, 1999, p.127)

In each case a particular perspective drives the nature of the criticisms made, both offensively and defensively. Each group appears to be attempting to preserve their own area of expertise whilst simultaneously accusing the other group of lacking that very same expertise. For instance, in this case the Old Humanists' argument was that school educators were teaching 'fuzzy' mathematics that lacked rigour and precision – two of the hallmarks of academic mathematicians. From a defensive perspective this criticism attempts to preserve the qualities they deem to be essential elements of the trajectory leading to becoming a mathematician (and

Old Humanists), while from an offensive perspective they are accusing school educators of lacking these very qualities. Similarly, the Progressive Educator response accuses the Old Humanists of lacking both humility and pedagogical skill, thereby defending the qualities they deem to be important in school educators whilst simultaneously attacking the Old Humanists for not possessing them.

This seems to illustrate quite clearly what is encapsulated by Restivo and Sloan (2007) when they say that "when we defend a particular view of mathematics or of the mathematics curriculum, we are defending a way of life" (p.12). Each group is both advocating for their own way of life whilst simultaneously criticising and attacking the other ways of living. This is reminiscent of the teacher educator discussed previously and reported in Sullivan et al. (2000) who critiqued a mathematics lesson for using a supermarket as an exemplar instead of a State owned enterprise like a school or hospital. Such a comment seems to contain an implied defence of the Public Educators' position by offering a social justice critique of the observed lesson. At the same time it seems to contain an attack on what was perhaps perceived to be a Technological Pragmatist undertone in the lesson that promoted capitalism, profit, and work readiness.

If such critiques really do arise from different ways of life, then it seems unlikely that they can be resolved rationally, for the adoption of one lifestyle over another is no simple task to understand, and most likely represents a lifetime of experiences rather than a handful of convincing arguments. So the question of who should decide about school mathematics seems doomed to rely on the personal taste and lifestyle of whichever group/s capture the ear of decision makers and the public imagination. However there may be some clarity to be had in exploring the second aspect of my self-analysis, namely the relevant domains of expertise of each group.

7.3.1 Social interest group areas of expertise

Society is quite clearly dominated by some of Ernest's (1991) perspectives more than others, and certain sectors within society operate under quite distinct cultures that do not translate well into other sectors. For instance, football operates under quite different rules and mores than would be tolerated in the broader public culture – it is not acceptable to bump or hurl someone to the ground in the local supermarket, school, or hospital. Similarly it is not usually acceptable to wear ‘street’ clothes at school. Each of these sub-cultures operates with its own set of guiding principles, some of which are more explicitly or formally stated than others. School uniform policy is typically a public document, whereas the expectation to drink as many beers as possible after a match is often an unstated rule within some sports clubs.

These compartmentalised sub-cultures sometimes clash with each other, or with the dominant public culture which can lead to well publicised scandals, such as occurred with the exposure of the institutionalised culture of police corruption in New South Wales (Wood, 1997). In that case the dominant public culture forced changes onto the New South Wales policing culture so as to alter the nature of the sub-culture into one that no longer collided with public mores. Ostensibly the ‘math wars’ is another instance of sub-cultures clashing with each other over disputed territory, some of which reside in the public domain. It seems that once a dispute enters public territory, such as the education of society’s children, then the dominant public culture is likely to intervene and force changes on the sub-cultures to eliminate aspects which are in conflict with the broader social views. Whether this has actually happened in the realm of mathematics education remains to be seen.

One way forward that endeavours to honour and respect each of the disparate world views is to attempt to mark out more clearly the territory which each sub-culture or social interest group could plausibly claim as their own without clashing with the interests of other groups. In Table 7.2 I have provided one possible rendering of the domains that might be considered the most appropriate concern of each of Ernest’s (1991) interest groups. Separating out the areas of appropriate concern also helps to clarify the kinds of mathematics that is particular to each domain and give some sense of the proportion of the population who might require those kinds of mathematical skills.

Table 7.2 Proposed mathematical domains of concern appropriate to each social interest group.

Interest group	Industrial Trainers	Technological Pragmatists	Old Humanist Mathematicians	Progressive Educators	Public Educators
Appropriate Domain of Concern	Mathematics designed specifically for transition to the workplace – e.g. apprenticeship transition courses	Workplace based research and development mathematics	University based pure mathematics research and specialist tertiary mathematics courses	Pre-school and Primary school mathematics	Secondary school mathematics and teacher education
Type of Mathematics Relevant to each Domain	Workplace specific functional mathematics	High end specialised applied mathematics	High end specialised pure mathematics	Basic domestic and common numeracy	Critical numeracy that equips students to question and evaluate the claims of others
Indicative Size of Relevant Audience %	50 (All employees requiring some workplace specific mathematical skills)	0.4 (Engineers, scientists, researchers etc.)	0.4 (Tertiary students majoring in mathematics)	100 (All pre-school and primary students)	100 (All secondary students)

The division of mathematics into interest group specific sections attempts to reflect where each group is primarily located within society. So, for instance, while the Industrial Trainers may wish to impose a sense of obedience and social hierarchy onto students in general, where their particular worldview is most plausibly relevant is in preparing students for direct entry into the workplace (e.g., trade apprenticeships), or the training of existing workers in mathematical functions specific to their jobs. In these situations it is neither relevant nor appropriate to focus on abstract mathematical theories, nor to attempt a social critique of the students' or workers' chosen careers. There may be a role for mathematical critiques relating to safety, working conditions, financial planning, for example, but these might be better situated within the role of secondary school mathematics or the workplace union rather than that of the employer/trainer. In any case, the Industrial Trainer perspective has a valid place in deciding what mathematics should be taught, and to whom. Given the potential audience for this kind of mathematics would include all employed adults, and all students wishing to enter into apprenticeships, an Industrial Trainer approach to mathematics could reasonably be expected to impact on some 11,000,000 people across Australia (Australian Bureau of Statistics, 2010), or approximately 50% of the population.

While there is a considerable overlap between the mathematical interests attributed to Industrial Trainers and Technological Pragmatists in terms of work readiness, the more particular emphasis of Technological Pragmatists is on technological innovation and applied research, therefore they would more properly focus on the kinds of mathematics that would be used by engineers, researchers, and scientists. Given the specialised nature of these fields, the types of mathematics required here would also be quite specialised and sophisticated. Australia has approximately four researchers, engineers, and scientists per thousand employees (Organisation for Economic Co-operation and Development 2006, p.33). This equates to 0.4% of the population who would require proficiency in high end mathematics.

The situation is similarly rarefied for the kind of activities Old Humanists are chiefly concerned with. Around 18,000 students enrol in tertiary mathematics subjects each year, while less than ten percent of these major in mathematics (Thomas, Muchatuta, & Wood, 2009), with considerably fewer going on to postgraduate mathematical study. Taking mathematics majors as the benchmark, this equates to a rolling cohort of less than 1,800 people each year for, say 50 work years, or again about 0.4% of the population who could properly be considered to be within the domain occupied by the Old Humanists, that of tertiary and pure mathematics research, although in reality the majority of these students would go into careers other than mathematics research.

Given the compulsory nature of schooling in Australia, everyone could be expected to encounter the areas allocated to Progressive and Public Educators. Since Progressive Educators are more interested in the growth of the child than in questioning the nature of mathematics, it would be appropriate that they be given sway over pre-school and primary school mathematics rather than secondary school mathematics. It seems plausible that such personal growth would be closely tied to mastering the kinds of domestic and common mathematics associated with being competent members of society. Once this kind of foundation is in place, and as the emphasis shifts toward becoming a competent adult in secondary school, it seems reasonable to then introduce the Public Educator approach of critical mathematics where students develop skills in questioning, analysing, and evaluating claims made by politicians, advertisers, and other interest groups. Such critiques should assist students in formulating their own perspective on reality, and help them in formulating their decisions of how to live in the world – whether it be through a career, further education, domestic activities, or something else.

It is worth noting that the labels given to these perspectives, Industrial Trainer, Old Humanist and so on, do not relate to individuals per se since it is unlikely that there are people who are 'pure' types within Ernest's (1991) model, so it is not particularly useful to attempt to classify individuals according to the model. Rather, the real benefit comes from identifying the appropriate areas of mathematics that rightly 'belong' to each of these perspective. Doing so creates a clear demarcation within mathematics education where people can best channel their attention to adapt the appropriate aspect of mathematics education that best suit their purpose. It also demonstrates how problems can arise when one group attempts to control areas beyond their appropriate sphere of operation and expertise, tending to devalue the expertise of the group more properly concerned with those areas, and running the risk of imposing demands that are both impractical and inappropriate.

7.3.1.1 Interest group control and interactions

Undoubtedly there are areas of overlap between some or all of the five perspectives since it would be unusual for a person to subscribe to multiple perspectives without holding some kind of mental bridge that enables them to move from one to the other. Figure 7.1 offers an illustration of how these social interest groups might plausibly overlap with, and inform, each other.

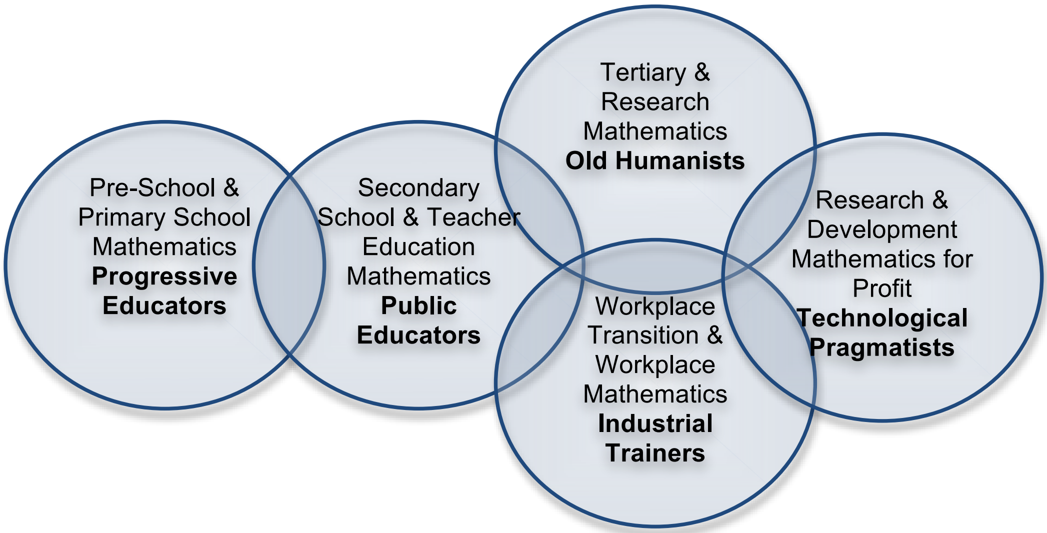


Figure 7.1 Illustration of how the five social interest groups might overlap with each other.

The diagram captures the obvious overlap between the interests, intentions, and expertise of primary and secondary mathematics educators, and highlights the gap that exists between the Progressive Educators and those located outside of compulsory education. It also reflects the fact that those engaged in profit based mathematics research will typically have mathematical expertise beyond that found in schools and most workplaces, and practical application experience beyond that of professional academic mathematicians. The identification of these groups by Ernest (1991) provides more than a description of the types of world views that have come to bear on mathematics education. There is, for some of the groups, an implicit level of control over certain areas of society. For instance, the Industrial Trainers represent the powerful elite within society who historically exercised a level of control over workplaces (and social order generally) and seek to preserve it. Technological Pragmatists control the businesses they own and use the products and profits of these businesses to justify their emphasis on applied, profitable mathematics research, while Old Humanists control the domain of pure mathematics research. In each case these groups represent a very small percentage of the population, and while their decisions and actions may directly impact on substantial proportions of the population, they themselves are largely above scrutiny within their sphere of direct influence since they are deemed to be the experts in their field. On the other hand, both Progressive and Public Educators are potentially large in number, large in impact, and typically under the close scrutiny of society. While all five groups are subject to various restrictions on their activities by virtue of laws, regulations, and bureaucracies, it is only the Educators who are actively dictated to in terms of the content and nature of their jobs. For instance, politicians, business entrepreneurs, and professors of mathematics are all essentially free to decide the nature of their efforts and pursuits. Teachers, however, are constrained by the structure of their classes, the content of their curriculum, and face having their pedagogical effectiveness judged by the performances of their students on national tests.

Additionally, since nearly everyone has personal experience of schooling, whereas few have personal experience of mathematical research, it is much more common for people, including Old Humanists, Industrial Trainers, and Technological Pragmatists, to hold opinions about school education. These opinions may take on a sentimental hue which works to devalue modern pedagogical approaches simply because they do not reflect the opinion holders' personal experiences of school. This could help explain the popularity of 'back to basics' approaches to mathematics, which might be more accurately described as 'back to the ways I am familiar with'. This also reflects the enduring memories of mathematics for the majority of the population who associate mathematics with basic arithmetic computations rather than more abstract topics like algebra and geometry, and a substantial proportion of whom believe mathematics is about getting the right answer regardless of understanding (Galbraith, 1986). As a result, school mathematics has become a hotly contested area in recent decades, with no clear expert group providing leadership.

In terms of educational leadership, it is widely acknowledged that teachers tend to be held in low regard by the community (Darling-Hammond, 2006), while teachers themselves hold myriad views of what constitutes best practice (Bol & Berry, 2005), and teacher educators are in turn often held in low esteem by practising teachers and other academics (Clarke, 2001). This situation could be seen as a school based educational leadership vacuum, which effectively opens the door to experts from other fields entering the fray. This influx of external experts further erodes the control of school educators whose influence wanes amid calls for greater accountability of teachers to:

- better prepare students for the workplace;
- prepare more students for the growing need of high-tech professionals in the information age; and,
- to do something to lift the falling standards of mathematics students entering university.

In short, these are calls for teachers to meet the demands and priorities of the other three social interest groups and to be accountable to them.

This loss of teacher control over school education due to the dominant influence of other interest groups places teachers in the untenable position of being forced to meet a set of externally imposed demands in addition to the coping with the pressures intrinsic to teaching. This situation is encapsulated in the notions explored in Chapter 4 of the 'good-enough teacher', wherein the expectations of being a mathematics teacher are becoming almost impossible to satisfy by a typical educated adult. The increasing external demands on teachers to be reflective professionals, to improve their teaching of mathematical concepts, and to better prepare students for national assessments – the results of which will be used to assess both the teacher and schools' performance – all originate from other interest groups. Few, if any, of these demands arise from either the Progressive or Public Educator worldviews. As a result, these external impositions increase the workload of teachers and squeeze out the kinds of activities they might otherwise engage in if they had greater autonomy.

Interestingly, all of these external demands come from perspectives that place the student second and social/industrial/academic demands first. And, perhaps not coincidentally, all of these demands arise from segments of the community that do not actually deal with the students in question, yet their perspectives and concerns over-ride those of the people who do deal with students on a daily basis. Once again this serves to undermine teachers' confidence in what they do, particularly if they do not possess the skills valued by the other interest groups, and particularly when those who might be considered their natural allies – teacher educators and educational researchers – subscribe to many of the views being espoused by other groups. Even the Department of Education and Early Childhood Development has adopted an Industrial Trainer perspective, contending that the fate of Victoria (and Australia) in a global economic environment lies in exciting young people about science, mathematics, and technology. It is not insignificant that their recent strategy document (Department of Education and Early Childhood Development, 2009a) was formulated to meet the proposals drawn from "business, industry, and research leaders" (p.3). There was no mention of teachers or teacher educators.

Nevertheless, if systemic inequities such as random inequity have arisen within mathematics education as a result of the external pressures of the various interest groups, then the approach to mathematics education may well collide with the broader public mores, resulting in steps being taken to rectify the matter. There is evidence that a collision of this sort may be looming, for instance, data presented in Chapter 5 around teacher workloads and confidence illustrates that many teachers appear to be doing their best, are working long hours, engaging in professional development, and yet still lack confidence in their mathematics teaching. Other research shows pre-service teachers continue to exhibit signs of mathematics anxiety and/or less than ideal mathematical skills (Hawera, 2004; Uusimaki & Kidman, 2004; Wilson, 2007) demonstrating that the problem of anxious and sub-optimally skilled teachers is unlikely to be alleviated in the near future by a steady influx of new teachers. Such data suggest that if, as indicated in Chapter 6, random inequity is already associated with up to 35% of teachers, then student disadvantage of this type is also likely to remain a feature of education into the foreseeable future. Alienation and disengagement from mathematics on such a scale cannot fail to collide with the broader public interests.

However, while such a collision is likely, it has not happened yet and the impact and influence of other expert groups on school mathematics continues unabated. Given that the two groups which impinge most directly on school mathematics are the Old Humanist and Industrial Trainer perspectives, I analyse some of the specific arguments associated with these views and attempt to highlight some of their weaknesses.

7.3.2 Old Humanist and school mathematics

The Old Humanist perspective on school mathematics stems, in the main, from academic mathematicians. They value the absolutist nature of mathematics and seek to preserve its rigour. Given their personal affinity for mathematics, there is a degree of intolerance directed toward those who do not readily grasp it, and some of the statements made by Old Humanists are tinged with degree of arrogance. The 'math wars' saw many professional mathematicians weigh into the debate, using their positions of authority to force through views not always supported by evidence (Schoenfeld, 2004). However, their own sphere of operation – university mathematics – is not as intact as is often thought to be the case. Additionally, there is an alternative version of Old Humanism that privileges the aesthetics of mathematics rather than the authoritarianism typical of Old Humanists engaged in the math wars. As a result of this different emphasis they each arrive at diametrically opposite conclusions about the nature and role of school mathematics. This section explores these issues further.

Academic mathematicians were, almost by definition, successful at school mathematics, and it is important to note that their experience of mathematics was likely to have been very different from the majority of people. It is therefore possible that they are ill equipped to empathise with those who struggled with school mathematics, and likely that their interests lie in preserving the kinds of experiences and pathways that they personally found useful as opposed to experiences and pathways that might be of benefit to students less interested in mathematics. They might also be seen as idealising certain features of school mathematics that they believe to be fundamental to mastering higher order mathematics. Instances of these could be their focus on formulae memorisation, teacher centric pedagogies, mathematical proofs, and obtaining correct answers to problems posed in text books, all of which have been advocated by academic mathematicians as part of the math wars and central to the Old Humanist perspective on school mathematics (Baker, 2010; Schoenfeld, 2004).

The credibility and authority of professors of mathematics were used in the math wars to explicitly push this Old Humanist perspective, culminating in the open letter (mentioned previously) that was signed by over 200 mathematicians (Klein, 2003). This public attack on school educators was further backed up by comments from Education academics who also subscribed to Old Humanist views, for instance teacher educator Professor Eric Hirsch made claims that "only through intelligently directed and repeated practice, leading to fast, automatic recall of math facts, and facility in computation and algebraic manipulation can one do well at real-world problem solving" (Becker & Jacob, 2000, p.535). Schoenfeld (2004) described such claims as dubious and reflective of a willingness to engage in highly political actions and to use positions of authority to bring about changes in lieu of having compelling evidence. It is worth pointing out that in the realm of rational debate, one good argument trumps any number of signatures.

However, as the math wars heated up, mathematicians Mannix and Ross (1995a) wrote about a number of myths that they felt were damaging mathematics education. They pointed out that the end of the Cold War had dramatically reduced the demand for advanced military research and development, resulting in thousands of mathematicians, engineers, and scientists being laid off and seeking academic positions instead. Similarly, global competition had forced most high-tech industries to reduce staffing and relocate overseas (away from the U.S.A), while international collaboration on scientific projects further reduced the demand for duplication of scientific expertise in each participating country. Pressure on tertiary institutions budgets was also working to reduce the number of academic positions available, the nett result of which was that overall growth in demand for scientists, mathematicians, and technologists was nowhere near as dramatic as had often been claimed to be the case.

Additionally, Mannix and Ross (1995a) nominated Information Technology as another industry often claimed to be experiencing exponential demand for mathematically competent employees, but which was nothing of the sort. They point out that rather than requiring ever increasing mathematicians to develop new software, most existing software can be modified for new applications without any specialised mathematical skills. Thus, rather than having to start from scratch on each project, new computer programs can leverage or modify existing software libraries that have already been developed. This is one of the great benefits of Object Oriented programming wherein complex calculations and functions can reside in custom built binary libraries, greatly reducing the demands on a software engineer. For instance, instead of having to write thousands of lines of code to make an object appear to move across a screen as if effected by gravity, wind resistance, and collisions with other objects, a programmer can simply 'call' existing libraries which have already been developed to perform the required calculations. Mannix and Ross (1995b) point out that this kind of technological revolution has effectively eliminated entry level mathematics and science jobs that previously involved ‘crunching numbers’ for common, time consuming analytical tasks.

In stark contrast to the comments of Hirsch quoted above, Mannix and Ross (1995b) claim that even “many mathematics Ph.D.’s are not adept at solving problems that arise in the real world” (p.40). This illustrates the capacity for even tertiary mathematics curriculum to become removed from daily life, and according to Mannix and Ross (1995b), no tertiary mathematics qualification provides students with the marketable skills that they will need to participate effectively in a peacetime economy being driven by fields such as biotechnology and telecommunications. More recently, Solomon (2009) has shown that undergraduate students are led to believe that mathematics is about learning rules, reproducing solutions, working speedily to obtain correct answers, and that creativity is impossible within pure mathematics. If these are the hallmarks of tertiary mathematics education it is entirely consistent that authoritarian Old Humanists would resist reforms within school mathematics that violate such principles.

There is, however, another Old Humanist view of school mathematics that endorses a very different approach to school mathematics compared to those expressed in the math wars. Rather than pushing mechanical mathematical skills that will ‘discipline the mind’ in preparation for university mathematics, this view endorses the exploration of mathematical concepts in the way many professional mathematicians explore mathematics. It is the aesthetic version of Old Humanism as opposed to the authoritarian version discussed above. This view is encapsulated by a piece written by a mathematics teacher (Lockhart, 2008) in which he draws an analogy between music and mathematics. He imagines a musician waking from a nightmare wherein society has made music compulsory to remain competitive in an increasingly ‘sound-filled’ world. Students are required to become fluent in the ‘language of music’, namely sheet music notation. Listening to and composing music are deemed advanced topics to be put off until such time as students have mastered jiggling symbols around according to strict rules, and have passed standardised tests on such things as modes, meter, harmony and counterpoint. It is considered imperative that all members of society should recognise modulation and fugues regardless of whether they are ever likely to actually hear one or not. Lockhart (2002) laments that school mathematics destroys children’s curiosity and love of pattern making through a series of “senseless [and] soul-crushing ideas” (p.2). Instead, he advocates playing with mathematical ideas so that an appreciation of their beauty, simplicity, and power can be attained. He advocates mathematics as an art form rather than a set of mechanical rules, and believes that by concentrating on formulae as facts to be remembered, without understanding how these formulae arose from creatively thinking about problems, renders school mathematics a pale imitation of mathematics proper.

This aesthetic version of the Old Humanist perspective shares much with the Progressive Educator view in terms of encouraging students to explore, develop, and discover mathematics, instead of being force fed disconnected theories. The authoritarian version of Old Humanism is arguably motivated by a similar deep appreciation for the art of mathematics, but instead of endorsing experimentation it seeks to preserve 'the old ways' of school mathematics that its adherents benefitted from personally. Yet, as demonstrated by Mannix and Ross (1995a), while the authoritarian Old Humanist camp may be seeking to shore up traditional approaches to school mathematics, they may soon come under pressure themselves to improve the efficacy, efficiency, applicability of advanced mathematics education. Doubts about tertiary mathematics weakens the Old Humanists' case for what school mathematics should be modelled on, since the area of mathematics education under their direct control may itself be in disarray. Drawing attention to such things might be of benefit to Public and Progressive Educators in relieving some of the pressure they are under from the Old Humanist camp, and giving them a stronger voice in reconsidering what is important in the mathematics curriculum.

7.3.3 Industrial Trainers and mathematics as work readiness

Although Ernest (1991) emphasises the authoritarian, political, and right wing aspects of the Industrial Trainer perspective, I focus instead on the work readiness aspects of this view, and the advocacy of a *back to basics* approach as being central to producing a competent and efficient workforce. This section examines some of the scholarship which has linked numeracy to poor employment outcomes, and highlights some of the flaws in the arguments put forward. Here I endeavour to demonstrate that rather than being a solution to social disadvantage, mathematics may well be complicit in bringing it about.

There is a common sense appeal to the Industrial Trainer position that school mathematics provides an important service for employers. Galbraith (1986) interviewed 660 people and found that 86% believed that employers are entitled to expect school leavers to be proficient in work related calculations. Therefore, mathematical proficiency helps employers to identify which job applicants are likely to possess a greater ability to perform increasingly technologically based duties. Additionally, because performance in mathematics is colloquially associated with overall intelligence – for instance, nearly 70% of Galbraith's (1986) cohort viewed mathematical skill as a proxy for 'smartness' – high performing students are seen as offering employers a greater capacity to fulfil their roles intelligently and to therefore potentially make profitable contributions to the company as innovators and future leaders (Yorke, 2009). The structure of the existing education system helps to foster this achievement-centric view. Students' performances are rated throughout the compulsory years of schooling and culminate in a year long, State wide, academic contest. Performances on the Victorian Certificate of Education (VCE) are then compared in order to award limited tertiary places to the most successful students. This competitive nature of schooling has been in place for decades, and is central to the received view of what constitutes 'real' education.

Non-competitive applied learning alternatives to the VCE such as the Vocational Education and Training (VET) and Victorian Certificate of Applied Learning (VCAL) have lower prestige and are thus held to be of lower value than the academic VCE qualification – even by Industrial Trainers, despite the explicit focus of these qualifications on work readiness.

Graduates of tertiary education are considered to be even more desirable to employers, and therefore attract higher paid positions relative to those who possess lower qualifications. In a similar way those who have completed either VCE, VET, or VCAL are more desirable to employers, and higher paid, than those who have left school without completing any qualification. Of all the subjects available in VCE, mathematics is one of the most prestigious. It is worth noting that VCE mathematics only incorporates 33% of school based assessment into the final score, while the majority of other studies use 50% or more of school based assessment (Victorian Curriculum Assessment Authority, 2009). This emphasis on external examination is integral to the prestige associated with VCE mathematics, making it one of the ways of distinguishing between those with otherwise equivalent qualifications (Department of Education and Early Childhood Development, 2009a). Thus the Industrial Trainer perspective places mathematics in the dual role of providing valuable skills for businesses on the one hand, and as a valuable discriminator between otherwise similarly credentialed job applicants and tertiary place aspirants on the other.

The links between mathematical skills and employment have been given empirical support by research linking levels of numeracy skills with levels of unemployment. For instance, Bynner (2004) draws on two British longitudinal data sets to assess the significance of literacy and numeracy on progression in the labour market. He concludes that of the two, numeracy carries more significance in terms of labour market effects, particularly for women, reinforcing the conclusions of other similar studies that demonstrate the links between early departure from full-time education and the subsequent patchy employment history of people with poor numeracy (Bynner & Parsons, 1997, 2000; Parsons & Bynner, 2005). The overarching argument of these studies is that there is a causal link between the observed correlations between peoples' poor performance on numeracy tests and these same peoples' poor employment experiences (unemployment and/or low-skilled employment). The authors conclude that poor numeracy is a barrier to people accessing more desirable jobs. Additionally, since correlations are also found between poor numeracy and access to pension schemes, not voting, having no interest in politics, having poor health, being depressed, and feeling a lack of control over their lives, the authors extend their conclusion to "poor numeracy imposing difficulties for functioning in all areas of life" (Parsons & Bynner, 2005, p.36).

Such a conclusion certainly fits the common sense view of education, that if you do well in school you will do well in life or, more particularly, if you do well in mathematics, you will do well in life. However, there is an obvious fallacy inherent to this line of reasoning. First, correlations are merely that, regardless of how strong they are. For instance there is likely to be a striking correlation between ice-cream sales and shark attacks. This does not entail that warning stickers should be placed on ice-cream cones nor that Mr Whippy vans should be banned from beach car parks. So while there may be underlying causes that explain the correlation between numeracy test results and employment history, there is little evidence to suggest that numeracy test results (nor the lack of mathematical skills they claim to represent) stop people from wanting to vote, for instance. Yet Parsons and Brynner

(2005) suggest that improving numeracy skills amongst disadvantaged people can save them from social exclusion, which is potentially no different to stopping one's children from eating ice-cream to save them from sharks. The causal connection between numeracy scores and social exclusion is unlikely to be this direct.

A more compelling explanation of the observed correlations may be to view them as symptomatic of the way that education is currently structured, and that the poor numeracy results are symptomatic of those who did not succeed in the competitive education environment. A thought experiment might clarify this point. Imagine the reverse situation where nearly all students grasp mathematical concepts with ease and that succeeding at mathematics is no more difficult than, say, breathing. It seems extremely unlikely that such mathematical proficiency would preclude people from being unemployed or from ever becoming depressed. Something similar to this scenario is described by Mannix and Ross (1995b) where they report approximately 800 mathematics PhD's annually competing for around 500 academic jobs. So instead of a world devoid of undesirable experiences, what we might reasonably expect is that mathematics would no longer be considered a prestigious part of schooling, and that some other *sift and sort* mechanism would replace it as a discriminator of choice when selecting students for scarce employment or university places.

This hypothetical is only a slight variation of things as they currently stand. Few would argue that breathing, vision, manual dexterity, language, and a host of other common human traits, are not essential to the technological world we find ourselves in. If mathematical prowess became as ubiquitous as any of these other innate capabilities (which is already the case for pattern recognition, counting, logical thought etc.), then it would likely become as innocuous and competitively inert as any other commonplace human abilities that we currently take for granted. By contrast, the ability to fly, read minds, teleport and so on would radically change society in unimagined ways, as would other fanciful, though vaguely more possible, changes such as ubiquitous political engagement, universal moral action, or the valuing of relationships over power. Compared to these other imaginary abilities it seems highly unlikely that universal mastery of mathematics could be the panacea for the difficulties of life or hold the key to a utopian society.

Also there are, of course, many happy and successful individuals who have very poor numeracy skills. So it is clear that mathematical skills are neither necessary nor sufficient to guarantee a successful and happy life. It is far more likely that the unfortunate correlations observed by Parsons and Bynner (2005) do not arise from a lack of numeracy per se, but rather from the role numeracy plays in relegating people to having unfortunate experiences. To put it another way, school mathematics helps to determine who will end up on which path in life, but if mathematics was unable to be used in this way, then something else would be used instead. If this something else was skin colour, for instance, then the same kinds of correlations would be (and have been) observed, and it would be just as misguided to advocate improving peoples' skin colour to improve their lot as it is to advocate for improving peoples' numeracy.

Another problem with the Industrial Trainers' analysis is that school based mathematical proficiency appears to be a limited, rather than enduring, achievement. As Parsons and Brynner (2005) themselves point out, "if numeracy skills are not used in employment they are likely to decline" (p.35), in other words if you don't use it, you lose it. This is borne out by the reported discomfort many parents experience trying to help their children complete primary school mathematics homework (McKimmie, 2003; Else-Questa, Hydea, & Hejmadia, 2008), and also by the higher performance of younger people than older on quantitative literacy tests (Organisation for Economic Cooperation and Development, 2005). Many parents, and adults generally, have little cause to perform the kinds of mathematical tasks expected of school children, so the mathematical skill level of adults can reasonably be expected to be lower than those of young people.

From the Industrial Trainer perspective of preparing students for the workforce, if mathematical skills deteriorate without use (as is probably true of all skills) then there seems to be little value in demanding high levels of attainment from all students prior to entering a workplace, since relatively few will end up using them. For instance, if the performance of adults on numeracy tests reflects the extent to which they consistently use their mathematical skills at work, then presumably only 27% of the Parsons and Brynner (2005) cohort needed good mathematical skills for their work, since that is the proportion who demonstrated good numeracy skills. If little more than a quarter of adults use mathematical skills at work, it would seem to be a highly inefficient use of resources to impose high numeracy expectations on all school students. Doing so effectively squanders resources on developing proficiencies that, in most cases, will not be used. Furthermore, there is evidence to suggest that training employees in mathematics that is specifically targeted at their occupation is considerably more successful, and less likely to be rejected by adult trainees, than traditional mathematics instruction (Hoyles, Noss, Kent, & Bakker, 2010). Similarly, Mannix and Ross (1995b) report that many scientists and engineers feel that advanced mathematics is best learned within the specific context of their discipline. So it would appear that employers would actually be better served by customised vocationally based training instead of universal school mathematics.

A corollary problem exists for Parsons' and Brynner's (2005) analysis. As already noted, the mathematical skills of those who obtained high numeracy scores had most likely been engaged in work that utilised those skills. Therefore, those who obtained low numeracy scores might reasonably be expected to be engaged in work that did not utilise those skills. However, instead of attributing low numeracy scores to employment that did not require high numeracy, Parsons and Brynner (2005) assume that those who performed poorly on the numeracy tests always had low numeracy skills. It is this assumption that underpins their advocacy for improving numeracy levels amongst disadvantaged youth as a way of improving their prospects. Yet there is nothing to say that rather than starting from a low numeracy base and retaining it throughout their adult years, those who performed poorly started with high numeracy skills which simply faded away through lack of use. By the same token, there is nothing to suggest that those with high numeracy skills did not start from a low numeracy base that was subsequently improved by workplace experiences and training.

The same could not be said of the situation where mathematics acts as a filtering mechanism, since only those with high mathematical skills upon leaving school would be amongst the 27% whose jobs involved explicit mathematics. But it is important to remember that Parsons and Brynner (2005) are speaking of numeracy qua numeracy, not numeracy as a social discriminator. That is, implicit to their suggestion is that numeracy, in and of itself, can improve people's circumstances, ignoring any role mathematics might play in determining what life paths are open to them. However, it is inconsistent to suggest that improving young peoples' numeracy will enable greater numbers of them to gain access to more desirable careers, as is demonstrated by the imaginary world where mathematical ability is innate. As soon as a discriminator is unable to discriminate, something else needs to be used instead, so improving the numeracy of the 73% who did not require higher numeracy levels for their work merely shuffles which individuals get into the 27% of positions that use higher levels of numeracy rather than eliminating the 73% of positions that do not require high numeracy skills.

Since it is unclear whether the people in the study started with low numeracy that improved through employment, or the started with high numeracy that faded, it might be reasonable to assume that a person's base numeracy level is linked to the completion of school qualifications. If this is a reasonable assumption, then one might expect to find that those in the high numeracy group obtained significantly higher qualifications than the average or low numeracy groups. However, Parsons and Brynner (2005) found no significant difference in school qualifications between those exhibiting poor numeracy and those exhibiting competent numeracy. In fact, low and very low numeracy scores were very common, accounting for 48% of the sample, even though only 7% of the cohort were early school leavers and who might have been expected to have started out with low numeracy skills. This further weakens the assertion that improving students' mathematics skills is a means of averting social exclusion, since nearly half of the 11,000 plus participants in the longitudinal studies had low numeracy skills. If anything, those with good numeracy skills were in the minority (27%).

Attributing undesirable life outcomes as a direct causal consequence of low numeracy levels ignores the role mathematics plays in employee selection. It is an unrealistic view of the labour market to believe that millions of jobs go unfilled because of a lack of adequately numerate applicants, and that if only applicants had better mathematical skills, more of these jobs would be filled. It is more likely that there are a limited number of such jobs, and that these are filled by employers selecting the most numerate applicants available. Therefore, the observed negative life outcomes for those with very low numeracy skills have likely arisen from the use of mathematical proficiency to discriminate between job applicants, in addition to the negative self image and anxiety that many develop as a result of school mathematics. So rather than being an antidote to social exclusion, it would appear that mathematics could be one of the mechanisms of social exclusion.

If this is the case then, and if mathematics does not lend itself to being acquired by students in an equitable way (due to random inequity for instance), then perhaps the emphasis on mathematics as a meritocratic discriminator is misplaced. Perhaps it would be better to reduce the range of mathematics skills expected to be mastered in the current mathematics curriculum, and to encourage employers to judge students in a more wholistic fashion based on a range of indicators in addition to mathematics performance. It seems that much of the public debate about school mathematics has been driven by Old Humanist and Industrial Trainer concerns that do little to further the educational outcomes for students and society generally.

7.4 *Summary of the chapter*

School mathematics has been described as being in crisis for several decades, with student enrolments dropping in post-compulsory years despite claims of increasing demand for mathematically proficient employees in an economy increasingly dependent on technology. However, there is some acknowledgement that many students are not interested in mathematics, and some doubt as to whether an educated person needs to be mathematically proficient (Fennema, 2000).

There are many schools of thought on this issue, and those that seem to have dominated debate to date can be seen as being authoritarian Old Humanists and Industrial Trainers in terms of Ernest's (1991) social interest groups. Their elitist ideologies accept that only a minority can expect to be truly educated, but that there is value in being exposed to a wide range of traditional mathematics. These ideologies are, in some ways, philosophically opposed to those of Public and Progressive Educators who advocate for socially progressive changes and seek to educate through creative, student centred learning. The clash of these different world views, even ways of life, is evident in the math wars.

I have argued above that each of these perspectives has validity, but only within particular domains that need to be clearly defined. It is suggested that Industrial Trainers have expertise applicable to transition into work and workplace specific functional mathematics, Old Humanists have expertise in university based pure mathematics and mathematics research, Progressive Educators have expertise in early years mathematics, and Public Educators have expertise in secondary school mathematics with a focus on critical numeracy or mathematics for informed citizenship.

While each group has specialist knowledge, the maths wars have illustrated where some groups have attempted to dominate areas more appropriate to other groups. For instance, Old Humanists and Industrial Trainers have seemingly attempted to set the curriculum and pedagogy of primary and secondary school mathematics based on appeals to authority, in the case of Old Humanist academic mathematicians, and based on potentially spurious claims around the impact of mathematics on employment opportunities in the case of Industrial Trainers.

While Industrial Trainers' approach would arguably be appropriate for 50% of the population in terms of employees who would require work specific mathematics skills, the Old Humanists' perspectives are likely to only be relevant to 0.01% of the population in the form of high end engineering, scientific, and pure mathematics. By comparison the Progressive and Public Educators' perspectives would be relevant to 100% of the population, yet their voices have tended to be drowned out by those of the other groups.

Whilst there are obvious ways in which the Old Humanists and Industrial Trainers could positively inform the practice of Public Educators, and they in turn inform the practice of Progressive Educators, the relationships instead seem to consist of dominance and control. As a result school mathematics teachers are effectively constrained by the demands of non-school educators, and held accountable to values that do not reflect or accommodate the daily pressures they face in dealing with rooms full of children. That is, teachers are forced to satisfy demands that may be achievable by exceptional teachers, but which are most likely impossible for competent, good-enough teachers to meet.

The reality of schools is that they are arguably staffed by good-enough teachers, but that the expectations placed on them by society, the education system, and themselves, render them to be and feel ineffectual. This in turn results in large segments of the student population being relatively disadvantaged through processes like random inequity.

The next, and final chapter, examines some other realities that are relevant to mathematics education, and explores a possible way of dealing with them by making school mathematics a more teachable subject.

CHAPTER 8

Rethinking mathematics education

> "I knew a guy who could build a nuclear reactor out of coconuts but couldn't fix a two-foot hole in a boat." (Gilligan from Gilligan's Island, Back to the Beach)

This Chapter attempts to draw conclusions based on the evidence and arguments put forward thus far. One of the overarching themes is that mathematics education research may be tinged with a certain suspension of disbelief when it comes to theories of best practice and placing expectations on teachers to fulfil them. This suspension of disbelief is not to the extent required to enjoy Gilligan's Island, but it is perhaps enough to fail to recognise the predicament competent, good-enough teachers have been placed in by trying to live up to these expectations. Teachers need to struggle with the realities of the classroom while educational researchers focus on any number of other aspects of pedagogy that they feel teachers should be dealing with too. Perhaps like Gilligan, good-enough teachers find themselves faced with having a hole in their boat while the Professor dwells on more esoteric matters.

Section 8.1 provides a synopsis of the material presented in previous chapters and builds upon the themes relating to equity and systemic gaps between classroom teachers and those seeking to influence school mathematics. Section 8.2 raises some further consequences of the mismatch between pedagogical theory and the chalk face. The third section puts forward suggestions of how school mathematics might be changed to improve the current situation, and Section 8.4 draws together the conclusions of the argument.

8.1 *Retracing the journey so far*

This thesis began with the intention of exploring a way to help mathematics teachers become better at their job. It was hoped this could be achieved by making it easy for teachers to become micro-researchers, posing their own questions, and reflecting on the results of their enquiries by using the Real Time Feedback System. Arguably the RTFS was successful in stimulating teacher reflections, and teachers seemed to respond positively to its use. Additionally, they suggested a number of modifications that they felt would increase its utility for them. However, of those teachers given the chance to use the RTFS on their own, none managed to actually incorporate it into their teaching practice. At the time I took this to be a reality that I could neither dismiss nor circumvent, and which represented an impediment to my original goals of developing a tool that teachers could use. While the RTFS may be better suited to being used by a Teacher Coach in supporting classroom teachers, my inability to get teachers to use the tool unaided brought about a realisation that this was not a failing of the teachers so much as a failure in myself for asking too much of them.

While the RTFS prompted teachers to reflect on their pedagogy, analysis of these reflections suggested that the teachers were more like technicians delivering content than like dynamic educators engaging in the kinds of reflective pedagogy advocated in the literature. Yet the teachers I had observed had struck me as committed, caring, and skilled individuals, the kinds of people I would be happy to have teaching my own children, but by some standards they appeared to be reflectively inadequate, having a narrow focus on the concerns of their own classroom, and on improving the uptake of the set curriculum. It was difficult to reconcile this discrepancy between my first hand experience of these teachers and what the literature advocates as best reflective practice.

The combination of this discrepancy with my own, potentially excessive, attempts to influence their behaviour, highlighted for me that teachers are often found to fall short of one theoretical construct or another, a phenomenon I also observed in discussions about whether teachers had nailed their lessons or not. It struck me that within mathematics education research there did not seem to be a consistent sense of what exactly constituted a good-enough teacher, which would make it difficult, if not impossible, for teachers to measure themselves against a reliable benchmark – or indeed for researchers to measure teachers against an accepted benchmark. It seemed that instead teachers were measured against a wide array of ideals, sometimes idiosyncratic to the observer, few of which teachers could hope to live up to.

Possibly related to the temperamental nature of judging performance, not all teachers were willing to be observed, perhaps because they could not be confident on how they would be judged regardless of how they felt about their own teaching. Of those willing to be observed, survey data revealed that the most ambitious teachers were over-represented, potentially skewing the views of researchers further in terms of what a career teacher looked like, and potentially insulating researchers from the less ambitious, good-enough teachers, who perhaps make up the majority of the profession. Those teachers willing to be observed also indicated intentions of wanting to leave the classroom sooner than those not willing to be observed.

This split between ambitious and less-ambitious teachers' attitudes to being observed is possibly indicative of different attitudes toward education, which might help to explain the observed difference in participation. For instance, ambitious teachers are probably more likely to move into managerial positions in schools. In doing so, they are also likely to come to those managerial roles with expectations that less ambitious teachers are motivated by the same things that they personally find motivating such as, say: meeting key performance indicators; demonstrating proficiency to a wider audience; having students score highly on standardized tests, and so on. This is not to imply that less ambitious teachers do not value such things, but they may feature lower in their priorities, or they may not feature at all were they not part of the external demands placed on these teachers. If school administrators do hold such views, then it could represent a systemic gap between those who wish to remain in the classroom and those who wish to be promoted out of it. This could further isolate classroom teachers from being able to control the conditions they work under and increase the pressure to satisfy other demands unrelated to the classroom.

In many ways this surmised gap between school administrators and classroom teachers mimics the observed gap between the expectations of researchers and the demands faced by teachers. That is, teachers who wish to stay in the classroom are plausibly motivated by different values and desires from those teachers who seek promotion, or those people who seek academic research careers. A possible analogy that might help clarify this situation is the different experiences by people in the workforce who choose to become parents compared to those who choose not to. Those who choose parenthood have demands and pressures directly arising from their choice that impinge on, and are additional to, the demands of their career. Women in particular have argued about the need for workplaces to take account of the demands of parenting, to allow for better work-life balances, and to counteract workplace pressures that encroach on their ability to parent properly (Losoncz & Bortolloto, 2009). In a similar way school administrators, educational bureaucrats, and education academics could be seen as pushing the needs of the education system over the needs of classroom teachers, which could be analogous to employers pushing the needs of their businesses over the needs of their employees' families. That is, if the values of good-enough teachers are not acknowledged, or are considered less important than the values of school administrations or researchers, then it would likely result in good-enough teachers being squeezed between demands external to their main area of concern in addition to those inherent to being in the classroom, just as parents may be squeezed between the demands of their workplace and the needs of their family.

Some evidence of this can be seen in the way school mathematics has been widely contested in recent times in the form of the math wars, where arguably the process just described can be seen at work within groups seeking control over the form and direction of school mathematics, in particular the groups identified as Old Humanists and Industrial Trainers. Some Old Humanist academic mathematicians have attributed their positive experience of school mathematics to the kinds of repetitive approaches that typically generate little enthusiasm in students who are not as mathematically inclined as these academics were when they were students (see Section 7.3.2). Thus at an even broader level, those with influence over what is to be taught, and in some cases how to teach it, are prone to systematic bias toward what they believed worked for them, which may be very different to what is required for those who lack scholastic enthusiasm. This push to teach mathematics the way that Old Humanists found helpful risks alienating many students, and possibly teachers.

Given that Old Humanists were successful at school, there is a strong chance that their instincts and advice are valid for similarly inclined and similarly motivated young people, but there is at least an equally strong chance that their instincts and advice are wholly unsuitable for those young people with different orientations – and clearly there are many students who are differently oriented.

The reasons for these different student orientations are undoubtedly complex and manifold, but as canvassed in Chapter 6, it is at least plausible that random inequity is implicated for many students. That is, through no fault of their own, many students have been disadvantaged relative to their peers in terms of poorer mathematical learning opportunities, and are more likely to have become disenfranchised with, or even alienated from mathematics. Compounding this problem is that many teachers seem to lack confidence as mathematics teachers even though most are, probably, good-enough teachers in other important ways.

This seems to leave us with two likely facts:

i) there are many teachers who are not well equipped to teach mathematics successfully, but whom are good-enough teachers in most other ways that matter; and,

ii) there are many students who, for whatever reason, are not disposed favourably towards mathematics.

Hence, even if there was unanimity on what constituted excellent mathematics teaching, efforts toward making good-enough teachers better would most likely fail due to the diversity of mathematical dispositions within the student population. This diversity of dispositions amongst students would render many of them unmoved by improved pedagogy, and the diversity of student orientation is also likely to be exacerbated by the range of mathematics teaching skills of the teachers they encounter. As a result, it seems teachers and students alike are locked into a vicious circle of failure.

It could be argued that this vicious circle is also due to the difficulties of trying to satisfy the demands of Old Humanists and Industrial Trainers in a setting not suited to doing so. That is, schools may be environments where it is not possible to successfully implement approaches inspired by Old Humanist and Industrial Trainer ideologies. If this is the case, and given these ideologies have succeeded in influencing school mathematics curriculum and pedagogy, then good-enough teachers may never be able to live up to the demands others place on them. Exceptional teachers who do manage to satisfy these demands only serve to perpetuate the romanticised myth that it is possible for everyone to do so, much as Jaime Escalante was dramatised in *Stand and Deliver* as a romanticised, unattainable ideal (Gieger, 2007). Just because some teachers can meet Old Humanist and Industrial trainer demands does not mean all teachers can, nor does it mean that other teachers are inadequate but that perhaps these demands are unreasonable.

Besides the impossibility of all teachers becoming exceptional teachers, the other reality is that many, perhaps the majority of people, are not particularly captivated by mathematics, and many students are not even captivated by school. This is not to say that the majority of students are incapable of succeeding at mathematics, but that most lack an abiding interest in mathematics, whereas the curriculum has been developed by people who do have an abiding interest in mathematics. Failing to produce curriculum that accommodate this reality is likely to exacerbate the problem further. For instance there is evidence of accelerating levels of student disengagement (Lamb, 2010), and the current push to keep young people at school until seventeen years of age (Council Of Australian Governments, 2009) could prove highly counterproductive to those who are not captivated by mathematics or school generally.

These two realities reinforce each other and work against any resolution of either one alone. For instance, if a magic wand could suddenly make all teachers excellent mathematics teachers, they would still face students who are unwilling to engage with mathematics (even in the absence of any form of inequity) since there just happen to be students who are not excited about mathematics. If the magic wand was instead directed at students so that all were rendered mathematically enthusiastic, then they would still face random inequity and a significant percentage would inevitably become disadvantaged, and increasingly likely to disconnect from mathematics.

In the absence of such a magic wand, or at least one that can alter both problems simultaneously, the combined effects of random inequity and student orientation serve to magnify each other. That is, students who dislike mathematics already and who have a disadvantaging sequence of mathematics teachers will have their disposition against mathematics reinforced, and teachers who are not well equipped to teach mathematics will find the job made increasingly difficult by a substantial proportion of disenfranchised students. This probably describes the current state of affairs in most schools, which has some serious implications relating to duty of care of the education system for both teachers and students.

8.2 *School mathematics and duty of care*

Schools are expected to be safe places for the people who work in them, and the young people who attend them. Schools have implemented Occupational Health and Safety principles in a bid to manage risks, minimise harm, and systematically manage health and safety in the workplace (Department of Education and Early Childhood Development, 2009b). However, there is evidence to suggest that mathematics is a source of psychological injury, as seen by the levels of mathematical anxiety reported by a number of primary teachers in Chapter 5.

While mathematics is sometimes referred to as an ordeal to be endured by young people, and has even been characterised as a form of archetypal academic *right of passage* in some settings (McNamara, Roberts, Basit, & Brown, 2002), it seems that rather than ushering young people into adulthood, integrating them as fully fledged members of society, and providing them a sense of worth and meaning (Campbell, 1949), school mathematics instead seems to fragment, alienate, and even cripple many students.

Burns (1998) contends that over two thirds of adults in the United States of America "fear and loathe math[ematics]" (p.166) while Jackson and Leffingwell (1999) report that only 7% of the 157 pre-service teachers they collected data from had uniformly positive experiences in mathematics throughout their educational experiences from kindergarten to college, or conversely, that 93% reported having had negative mathematics experiences.

The fact that mathematics is associated with such high levels of negativity suggests that reduced mathematics skill is not the only negative outcome. For instance, art is routinely taught in schools, and whilst not everyone is an adept artist, art classes in schools do not attract the same level of ill will as mathematics appears to. It is also notable that mathematics is associated with a recognised mental health disorder, with mathematics anxiety being a social phobia variant (American Psychiatric Association, 2000). This disorder appears to exist independently of dyscalculia, a learning disorder which is the presumed to be organically based and estimated to effect between 3% - 6% of students (Badian, 1999). So beyond the limitations imposed by failing to perform well at mathematics, there is a very real threat to the mental health of students.

At these dyscalculia prevalence rates it could be expected that one student per class might have dyscalculia, yet Probert and Vernon (1992) reported that 26% of over 9,000 undergraduates had moderate to severe mathematics anxiety. The percentage of high school students would presumably be higher than this, since only academically successful students progress to university, and mathematics anxiety is strongly correlated with academic failure (Jones, 2001; Ma, 1999; Ashcraft & Moore, 2009). So a mathematics teacher might expect to have six or more students with mathematical anxiety in each of their classes, and quite possibly might suffer from mathematics anxiety themselves. This could be expected to exacerbate any other negative factors associated with mathematics, since once a student develops anxiety around mathematics they are less likely to benefit from the efforts of teachers thereafter, regardless of the teachers' level of skill.

Interestingly, pre-service primary school teachers recorded the highest levels of mathematics anxiety of all college students tested by Hembree (1990). This might demonstrate that for those mathematically anxious students who did not fail academically and who managed to gain entry into tertiary studies, that a primary teaching career is perceived to involve the least amount, or the least threatening kind of mathematics. This could represent the nexus of the perpetuation of mathematics anxiety whereby mathematically anxious primary teachers transmit it to their students (Wood, 1988), and while there is little research that looks at mathematics anxiety in the first few years of schooling, there is evidence that this is when it may first manifest itself (Chiu & Henry, 1990 – in Ma 1999).

The prevalence of mathematical anxiety amongst students and pre-service primary teachers is well documented, with several researchers now invoking quasi-therapeutic techniques to help these students and student teachers overcome or better cope with their anxieties (Troman & Woods, 2001; Bibby, 2002; Furner, 2004; Wilson & Thornton, 2006; Wilson, 2007). The need to provide prospective teachers with psychological support to enable them to better deal with aspects of the curriculum they will be responsible for delivering, highlights the possibility that mathematics may be a source of psychological injury to students and teachers alike.

This raises a number of duty of care and occupation, health, and safety issues that do not seem to feature in the literature on mathematics education. Injuries are not unknown in schools, and many curriculum areas are particularly prone to student and teacher injury: sport; physical education; woodwork; art, and so on. In these subject areas steps are actively taken to minimise both the chance of injury and the severity of any injuries sustained. However, psychological injuries arising from mathematics does not feature as an area of concern within the risk management practices of schools. Preventing such injuries should be a worthy goal in its own right, however the long term implications of having a reduced capacity to compete with others additionally disadvantages those who do develop a mathematics social phobia.

There is also evidence that particular personality traits predispose some people toward, and perhaps improve their ability with, mathematics – for instance the heavily visual and abstract nature of mathematics privileging visual learners over tactile or auditory learners (Head, 1981). If certain segments of the population are innately disadvantaged in a broad social benchmark such as mathematics performance, then equity once again becomes an issue.

There is anecdotal evidence amongst teacher education academics of pre-service primary school teachers vomiting the night before their mathematics tutorials due to their mathematics anxiety. That a single area of the curriculum could have such a negative psychological, and somatic, impact on people suggests that its radical modification deserves serious consideration. If the current mathematics curriculum was not considered to be so vital to student learning as appears to be assumed, then a great deal of suffering might be avoided. Mathematics anxiety in both students and teachers alike might be reduced, and student disengagement from school and drop out rates might improve. Education departments might also avoid future class actions brought by people holding them responsible for injuries sustained at school.

The next section recaps the main points of the thesis and considers some ways in which school mathematics curriculum could be modified to help mitigate against the risks of random inequity, psychological injury, student disengagement, and placing unrealistic expectations on teachers.

8.3 *Connecting mathematics to human lives*

There are several key claims that have been made in this thesis:

i) There are no clear standards for what mathematics education researchers expect of good-enough mathematics teachers, which can result in unrealistic expectations of mathematics teachers, and a lack of appreciation of the real demands of the classroom.

ii) Many otherwise good-enough teachers are unable to teach mathematics properly through a lack of confidence, or knowledge, or appropriate ways of engaging with students. As a result, many students are randomly disadvantaged, a process exacerbated by teachers and students who have developed psychological injuries relating to school mathematics, all of which contribute to student disengagement from mathematics, and possibly school.

iii) The position afforded mathematics in society has resulted from the pressure of special interest groups who have distinct preferences for what mathematics should be taught, and how to teach it, not all of which are necessarily amenable to classroom settings. Also, while these interest groups have persuaded society that mathematics is the cornerstone to prosperity and gainful employment, these claims do not seem to be supported by analysis.

While these points are inter-related and impact on each other, it is perhaps the third which is the most significant in that it is arguably why mathematics has become so disconnected with the realities of life. Today mathematics remains a prestigious subject area, and has acquired the reputation of being central to the future success of economies, thus much effort in mathematics education has been directed toward equipping students with sophisticated skills that typically have limited application in daily life. As a result, many students find themselves being forced to learn complex and confusing concepts that have no clear purpose, and which are not part of their life experiences. Other curriculum areas share this lack of functionality, such as history, geography, and social science, however these other areas at least concentrate on aspects of human experience that students can relate to in obvious ways, whereas mathematics delves into realms almost wholly abstract and inhuman. Therefore mathematics has become a mechanical, widely hated part of schooling that has succeeded in being universally implemented despite there being no genuinely obvious connection to students' futures, much as would be true of, say, Latin.

This dislike of mathematics may arise from the way in which school mathematics is largely an unrealistic pursuit. Beyond certain basic actions, students do not see adults modelling mathematical behaviour, and their parents are often likely to have a poorer grasp of mathematical concepts than the students have themselves. This apparent mathematical void in the adult world also renders mathematics as something childish that is only encountered in school, and as children grow so does their desire to leave childish pursuits behind. Again this could be said to apply to other curriculum areas as well, but adults are more often encountered: making reference to historical events (history); discussing places to which they would like to travel (geography); and, commenting on the politics, social events, and changes occurring in society (social science), than they are to be found solving simultaneous equations or ruminating on index laws.

A starker comparison exists with literacy. High literacy skills are at least as important to economic success as numeracy skills, but because reading and writing are ubiquitous daily actions, literacy skills are an obviously part of the adult world that remain intact beyond school and are protected from deterioration through daily use. It is no surprise that higher levels of literacy are observed compared to numeracy – for instance Bynner (2004) reports only 6% of his cohort displayed very low literacy skills, while nearly four times as many (23%) exhibited very low numeracy. As a result, literacy skills are seen by students to be a relevant and important part of adult life since virtually all adults around them are continually engaged in literate actions, while much of school mathematics is seen to be irrelevant and designed specifically for school.

In this way school mathematics appears to have over reached. By attempting to have students develop mathematical skills which do not have obvious, if only occasional application, mathematics teachers are required to divert a great deal of energy into inventing other motivators for students to learn the material. One consequence of this has been the common belief amongst students that mathematics will somehow be useful and necessary to them in the future, even though they have no clear idea of what this might entail (Toomey & O'Donovan, 1997). Undoubtedly mathematical proficiency is both useful and necessary to those few percent of the population who will go on to become professional mathematicians, engineers, or researchers, but the vast majority of adults require little more than functional numeracy to perform their jobs and manage their daily lives. Beyond this, there seems to be little to be gained from forcing students to engage with topics beyond those readily applicable areas of mathematics, much as there is little to be gained from forcing all students to learn Latin.

Interestingly, many of the arguments about the utility of mathematics mimic those put forward in support of retaining Latin. For instance: it provides intellectual rigour; changing it would 'dumb down' the curriculum; it provides a fundamental grasp of essential concepts; it trains the mind; it is the hallmark of an educated person, and so on (Kaulfers, 1949). But just as mathematics lacks appeal today, so too did Latin in the past, for instance given the choice between digging ditches and learning Latin, John Adams is said to have *eventually* chosen Latin (Niles, Niles, Hughes, & Beatty, 1827). Faced with a similar choice, students today might stick with mathematics, but this would be hardly a vote of confidence. And just as society appears to have progressed despite the demise of Latin as the cornerstone of public education, it is likely that society would continue to progress without mathematics in its current form as an educational cornerstone, especially since there is reason to believe that high-tech and high skilled jobs do not require the kind of mathematical preparation central to current school mathematics curricula (see Section 7.3).

In light of the preceding discussion it seems curious that mathematics should occupy such a central place in the school curriculum. The arguments that mathematics is a necessary ingredient for a person to be considered educated were applied equally to Latin before it. There is possibly a case to be made that our current notions of the educated person stem from the likes of Peters' (1966) *educated man* and Hirst's (1974) *liberal education* – both of whom nominate mathematics as a pre-requisite – but it is sufficient to the purposes of this argument to point out that the notion of what constitutes a truly educated person varies widely between, and is perhaps a hallmark of, particular interest groups. For instance, almost by definition, Old Humanists would consider someone to be well educated who Technological Pragmatists might consider poorly educated, and vice versa. This recalls the argument that each group would be better served by focussing on their own domain and imposing their unique standards on what they directly control. In this way if a person wishes to become educated in the Old Humanist sense they might attend university, or if they wish to become educated in an Industrial Trainer sense then they might seek appropriate vocational training, and so on.

So from a functional perspective, other than as a selection mechanism, there appears to be little advantage to either employers or other aspects of the economy in placing high expectations on the mathematical skill levels of school leavers beyond functional and critical numeracy. Yet even in its capacity to serve as a discriminator for employers and universities, mathematics appears to be both inaccurate and harsh. Random inequity effectively subverts any notion of meritocratic selection that is based on mathematical performance, since success or failure has more to do with luck than ability. Thus, using mathematics as a selection criterion has the potential to reject many able applicants who, through no fault of their own, were disadvantaged relative to their peers. However, beyond this prevalence for false negatives in selection, there is also evidence that mathematics is actually a source of psychological injury, as seen in Chapter 5 and discussed in Section 8.2 above. Thus its credentials as an impartial discriminator are dubious, and it may be causing more harm than good along the way. This would suggest that mathematics curriculum is in need of an over haul.

8.3.1 A different approach to mathematics

A better approach to school mathematics may be to start from the realities of the classroom and make the curriculum something that is both manageable by good-enough teachers and more appealing to a greater range of students. Feinman-Nemser (2001) takes this process further by proposing that teachers design their own curriculum and leverage their professional community affiliations to refine their efforts and increase both their performance and conceptual understanding of pedagogy, producing problem-based, student centred mathematics lessons. However, this might represent a virtual revolt by Progressive and Public Educators which would most likely trigger yet another maths war that they are unlikely to win convincingly enough to make this a realistic solution.

An alternative to this, which would not preclude Feinman-Nemser's (2001) approach, is to argue that despite its claimed centrality to economic success, much of school mathematics remains foreign to students upon leaving school. The notion that the economy is dependent upon high-level mathematical skills belies the fact that the majority of adults do not possess these skills, despite having been expected to learn them at school. And while science and technological industries underpin the increased prosperity generated over the last century, it does not entail that high-level mathematics is essential to preserving this growth. For instance, surgery and other specialist health fields are endeavours requiring great skill, and the economic benefits that derive from having a healthy population are beyond dispute. Yet none of the skills required by a surgeon, over and above those required by a first aid technician, are taught in schools. Similarly, few (if any) of the skills that distinguish an astronaut from a taxi driver are acquired in school. Thus, it is possible to illustrate that there are many precedents where highly developed skills are acquired in a work place or specialised training setting, which invalidates the central claim that the pool of highly skilled future scientists and engineers is dependent on school mathematics. Professionals such as these could, and arguably do, acquire the mathematics requisite to their career as part of their formal training instead.

So beyond the basic arithmetic skills required to be a functionally numerate adult, I would argue that the only other mathematical abstractions desirable to an educated adult are financial mathematics, certain skills in critical mathematics in the sense of numeracy for citizenship, and perhaps an element of aesthetic mathematics. Any specialised workplace mathematics skills would be developed as part of any appropriate workplace training.

8.3.2 Functional numeracy

By functional numeracy I mean developing basic mathematics skills required to function successfully in a domestic setting. This would encompass such things as: an understanding of various units of measurement and how to manipulate them – for example scaling up a recipe to feed seven people, or calculating how much mulch is needed for a garden bed; mental calculations and estimations for adding up purchases, calculating discounted prices, comparing prices across different brands and quantities; time based calculations; distance based calculations; basic navigation skills; understanding calculations relating to utility bills, and so on.

The intention with functional numeracy would be to encompass the daily domestic mathematics skills needed to function with confidence in the world as a competent adult, being able to perform the calculations to sufficient accuracy as to meet the needs of a domestic environment, and perhaps to be able to shop successfully at Ikea.

8.3.3 Financial numeracy

Financial numeracy would encompass more than the basic money based calculations mentioned above. The intention here would be to better equip students to understand how to perform wage and loan based calculations. This would include an understanding of calculations relating to salary, taxation, and leave entitlements, as well as being able to better compare different products offered by banks, pay-day loan companies, and other credit agencies. Basic investment mathematics would also feature here, covering such things as superannuation, purchasing shares, term deposits and so on.

The types of areas covered, and the depth to which they would be covered, would be determined by their utility to a typical worker in enabling them to interact with an important area of life that currently leaves many adults baffled despite exposure to over a decade of formal mathematics. It is also both necessary and sufficient for students to engage with these concepts supported by technology rather than manual calculations alone, since technology makes it possible to explore the long term impacts and trends that make financial numeracy so important to people's lives, and which are beyond the scope of what is possible with manual approaches.

8.3.4 Citizenship numeracy

This aspect of school mathematics would involve curriculum designed to equip students with the ability to understand and to some extent critique the kind of statistical statements commonly used by politicians, journalists, and advertisers. This would encompass the basics of presenting data graphically, an understanding of basic statistics, and the ways in which different meanings can be attributed to the same data depending on how it is analysed and presented. There would also be some overlap here with financial numeracy in terms of teaching students how to understand public expenditure and the relative scale of millions, billions, and trillions of dollars.

Again, what to include and the depth to cover it would rely on the guiding principle of what a competent adult would benefit from understanding in making political and personal judgements about who to vote for, how policies may impact them and their community, and to be able to understand arguments that rely on statistical data. It is important to note that while much of this mathematics may be relatively simple, it is not trivial.

8.3.4.1 Critical mathematics and the good-enough teacher

Critical Mathematics is an area in the literature which seems to deal with many of these of issues of informed citizenship, but given its roots in Freire's (1970) political empowerment of underclasses, it runs the risk of sliding down the similar idealistic pathways of the reflective literature in advocating for social transformations through mathematics education. For instance, Gutstein (2003) has students explore race based disparities in home loan approvals to expound on individual and structural racism. Similarly, Peterson (2003) has students use US Federal budget data to discover such things as that purchasing a stealth bomber costs the same as employing 38,000 teachers for a year. The content of these similar approaches are particular to the teachers' world views, and a different teacher might choose to explore different areas, such as the impact of minimum wage policies on increasing unemployment, or exploring data they consider inconsistent with climate change theory (e.g., some believe there was a rise of global temperatures from the *little ice-age* of 1680 to their peak in 1998 that is independent of CO_2 levels, for instance Easterbrook (2011)). Regardless of which side of the political spectrum motivates them, each of these examples casts the teacher in the role of well informed social commentator in addition to their role as classroom teacher. Obviously there are exceptional teachers who can accommodate both roles into their pedagogy successfully, but to expect this of all teachers is to once again raise the bar on what is considered to be good-enough both in terms of teachers and students, making it decreasingly likely to be achieved.

Exceptional teachers will continue to excel at what they do, but an approach to mathematics curriculum that places exceptionality as a minimum standard will fail by definition. What is needed is recognition of what the minimum, or good-enough standard is. This needs to be based on what can realistically be expected of all people who choose to pursue teaching as a career. By restricting mathematics to areas already familiar to competent adults, and incorporating aspects of direct relevance and interest to competent adults, makes it eminently reasonable to expect qualified teachers to be equipped to meet such curricular and pedagogic expectations. Specifying the necessary, *and sufficient*, expectations that teachers need to meet provides the clarity teachers require to be able to diagnose and improve any problem areas in their practice.

The approach I am suggesting aims for no more than to help students to become people who can fend for themselves mathematically at home, in shops, at work, and in polling booths, whereas critical mathematics runs the risk of swinging the pendulum too far toward replacing current mathematics idealism that seeks to produce students who can integrate by parts, with a social critique idealism that seeks to produce students who can radically transform society. Replacing one extreme with another is equally unhelpful in that it leaves good-enough mathematics teachers having to shoulder the burden of facing up to their students in the classroom each day in addition to being a well informed political activist with a particular axe to grind.

Frankenstein's (2005) *politics of mathematical knowledge* is applicable to all sides of politics in terms of presenting data in ways that obscure or emphasise certain points. However, rather than deconstructing the ways in which particular hegemonies utilise such techniques to their advantage, I would suggest that there are at least two reasons why it would be better for students to develop skills in using data to suit their own purposes. First, dwelling on broad social justice issues illustrates that there are forces at work beyond the control of most adults and, *a fortiori,* students – somewhat defeating the purpose of raising their awareness in the first place, after all what exactly are they supposed to do about it? Second, the data required to analyse such issues originates from external sources that render them neither readily accessible by students nor personally meaningful to them.

Instead, the approach I am advocating could involve the collection of a variety of domestic data: how long different family members play computer games, or watch favourite television programs; who does which chores each week and how long they each take to complete them; how much pocket money students get; the relative costs of driving, riding, and walking to school, and so on. These data could all be presented in different ways to support, or challenge, particular arguments that students might like to make. For example, students might seek to prove that they help a great deal at home, so they might choose to display data by grouping their efforts with those of someone who does most of the work. They might compare their data to the average hours worked or number of chores completed by their peers to similar effect. Choosing what counts as a chore and what does not, and even how tasks are described could all influence the overall effect of a particular presentation to better suit their argument. For example, Figure 8.1 illustrates three different ways of presenting the same data relating to meal times at my home, one of which puts me in a particularly good light.

Task	Who	Time (mins)	Total (mins)
Sweep floor after meal	Amelia	5	5
Load dishwasher	Brodie	15	
Set table	Brodie	5	20
Cooking	Carol	60	
Prepare vegetables	Carol	10	70
Clearing table	John	10	
Dispose of scraps	John	2	
Unload dishwasher	John	5	17
Add powder to dishwasher	Richard	0.25	
Bring food to table	Richard	0.5	
Close dishwasher powder	Richard	0.05	
Get salt for table	Richard	0.2	
Open dishwasher powder	Richard	0.05	
Pass butter	Richard	0.05	
Pour water for everyone	Richard	0.5	
Turn on dishwasher	Richard	0.1	1.7

Figure 8.1 Sample domestic data showing I may do most of the work at meal times.

Such an exercise can show how a judicious choice of what to present and how to present it can leave very different impressions. If the pie chart of the number of tasks were the only display provided then I would seem to be doing the lion's share of the work at meal times, yet the time on tasks pie chart tells a very different story. The table has its own features that tell a mixed story because of the ease with which people can be lost in the detail, making it difficult to form an accurate picture of the overall situation, which helps to demonstrate the importance and utility of charts.

Having students engage in shaping the way data is presented to suit particular arguments could help them to understand how malleable statistics can be, to realise the kinds of decisions that need to be made in presenting data, and to gain a genuine appreciation of the expression "there are lies, damned lies, and statistics". This approach also avoids forcing teachers into the role of political activist and keeps the focus on the skills at hand rather than introducing further abstractions from social science, politics, economics, social justice theory, or postmodern hermeneutics.

8.3.5 Aesthetic mathematics

Reducing the school mathematics curriculum to developing skills which all students will need as educated adults would significantly reduce the pressure on both mathematics teachers and students. Teachers would be able to provide genuine, real world exemplars for all topics either from their own lives or in a form readily identifiable by students as being anchored in reality, and students would be able to see an obvious connection between what they learn in school and what will be useful to them once they leave.

Such an approach would entail a severe pruning of the mathematics curriculum with several years worth of topics being removed. Doing so would allow the remaining material to be spread out over a greater period of time, allowing teachers to focus on developing student mastery rather than feeling the need to plough on regardless of how many students have actually grasped the concepts covered. In this way mathematics teachers could aim for students to develop deeper understanding rather than rapid progression, and to potentially build a greater appreciation of the aesthetic aspects of mathematics as advocated by Lockhart (see Section 7.3.2).

This aesthetic dimension of mathematics might be incorporated more explicitly into the reduced curriculum by including puzzles and the like as part of school mathematics. Many adults enjoy puzzles and brain teasers, and it is perhaps a shame that this fun dimension of mathematics has been squeezed out by the pressure to cover so much material that is not fun. In a similar way other mathematics topics could be incorporated into this more aesthetic component by covering concepts children and adults alike are often fascinated by. For instance, notions of infinity, fractals, certain elegant proofs, and the mathematics inherent to music, art, textiles, and choreography. Lockhart gives some examples of mathematics as play (Devlin, 2008). For example, he wonders how much of a rectangle is taken up by a triangle drawn inside of it, as shown in the left diagram of Figure 8.2.

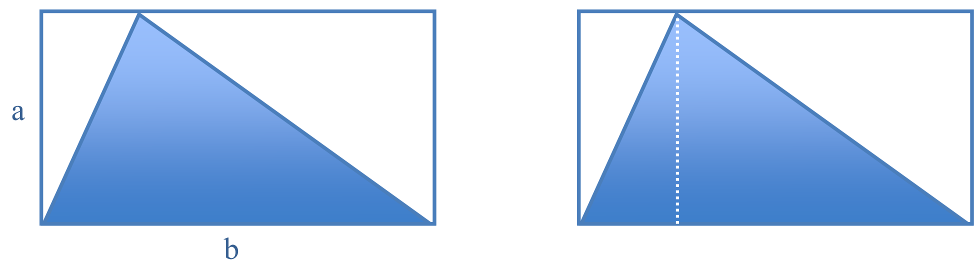


Figure 8.2 How much of a rectangle is taken up by a triangle?

While there are many ways to approach this relatively inane question, one elegant approach is to add the dotted vertical line as shown in the second diagram in Figure 8.2. This suddenly makes it obvious that there are two smaller rectangles each of which is cut exactly in half. Thus, the area taken up by the triangle in the first diagram is also exactly half of the overall area of the rectangle. Extending this concept further, the situation can be reversed. That is, it is possible to ask what is the area of the triangle in the first diagram, then draw the rectangle to enclose it, and use the same reasoning applied before to realise that the area of the triangle is exactly half of enclosing rectangle. Or put another way, the area is $\frac{1}{2}ab$, which generalises to all triangles. Reclaiming play in mathematics is perhaps where Old Humanist and Progressive Educator ideals overlap to a certain extent, but such play is quickly killed off in current mathematics classrooms by batteries of triangle area formulae questions. To encourage students to play and explore in this way requires time and freedom from traditional mathematics assessment, and the purpose would be explicitly to stimulate thinking and discovery and not to teach the mechanics of calculating areas.

8.4 *Saving students from mathematics and mathematics from itself*

The emphasis on, and dominance of, mechanical calculation is likely to contribute to students being turned off of mathematics. Beyond being turned off of mathematics, there is evidence that mathematics is an overall factor in student disengagement from school generally. Lee and Burkam (2003) found that 18% of school drop outs avoided mathematics in their first two years of high school compared to only 5% of non-drop outs. They also reported that a one standard deviation increase in 'average student-teacher relations' was associated with an 86% reduced chance of students dropping out. That is, schools where students reported better relationships with their teachers had considerably lower levels of students dropping out. Other studies have similarly indicated that improved student-teacher relationships reduces the likelihood of students dropping out (Davis 2004; Gassama & Kritsonis 2006; Hughes & Kwok 2007). Arguably the over stretched and abstract nature of current mathematics curricula alienates students and therefore detracts from interactions between students and teachers. For instance, Galbraith's (1986) survey of 660 adults showed only 14% preferred their mathematics teachers to their English teachers while 47% preferred their English teachers over their mathematics teachers. Changing the mathematics curriculum to cover practical topics could save it from trying to achieve too much, thereby reducing student cynicism, and increasing job satisfaction for mathematics teachers by being able to demonstrably teach meaningful material. Further, eliminating the pressure to cover swathes of material and to actively encourage mathematical play can only help to improve relations between teachers and students – although there will always be an element of the profession who will identify with Perso's (2006) calculus teacher who doesn't "do student relationships" (p.40). Such attitudes are fostered by an environment that is devoid of any clear minimum standards. In such a situation, excellence in mathematics can easily be seen as all that matters, whereas relating to students is clearly important. This reinforces the first point above in Section 8.3 that there is no clarity around what makes a teacher good-enough, which both feeds into and arises from a lack of appreciation of the demands of the classroom.

As things currently stand many mathematics teachers see the their job as delivering a set of pre-packaged rules and templates that satisfy prescribed policies. Some teachers feel that they only need to know enough to cope with the trickiest of questions that might arise from a student, which is why Kenschaft (2005) was able to find primary school teachers who were content with not knowing how to calculate the area of a rectangle because such knowledge did not feature in the curriculum they were expected to teach. Similarly, high school teachers only need to be familiar with the content contained in the relevant chapters of the set text book, and time constraints (amongst others), precludes them from setting aside class time to engage in mathematical creativity or play. By constantly failing to meet the demands of a difficult curriculum, many teachers are contributing to an endemic process of random inequity in schools, the second key point mentioned in Section 8.3.

Thus, pertaining to the third point of Section 8.3, it seems that society may be mistakenly asking too much of the mathematics curriculum by expecting it to bear the burden of economic prosperity, when in fact the kinds of skills expected to result from school mathematics are transient, and most likely better developed within the specialised context where they will be used. As a result of these high expectations, the mathematics curriculum in turn appears to be asking too much of teachers who are then forced to ask too much of students, resulting in many becoming disengaged from mathematics and school, which is strongly linked to poorer life outcomes. In many ways mathematics needs to be saved from school mathematics, as do teachers, students, and society generally.

By stripping out those areas of the mathematics curriculum which are largely meaningless to students and teachers alike it would be possible to reinvent mathematics as a vibrant and important part of schooling that equips students for adult life by giving them command over functional, financial, citizenship, and aesthetic numeracies. It would arguably transform good-enough mathematics teachers' jobs from being near impossible to both manageable and enjoyable.

It may be the case that mathematics has come to represent in modern education what Latin represented in the 1950's. What society is more likely to benefit from is citizens who can look after their mathematical needs at home, in shops, in handling their finances, understanding public debate, and with a disposition toward tackling problems, rather than simply being able to demonstrate prescribed proficiencies in a range of disconnected explicit mathematics techniques.

Further specialisation and more advanced mathematics could be taught at university to those who need them, after students have made significant decisions about their future pathways. This would be a more efficient approach than imposing high levels of mathematics on all students just in case they need it. It is also the approach adopted in many other areas of specialisation such as medicine, law, mechanics, philosophy, archaeology and so on, with some universities delaying specialisation even further by offering only postgraduate study options for gaining entry to certain professions.

Arguably the tertiary sector has pushed the responsibility for teaching students down to the primary and secondary years of schooling as part of an Old Humanist manoeuvre that allows them the freedom to criticise schools for poor performance while using their own filtering mechanisms to accept only the most academically talented students. Teese (2009) has pointed out that if universities themselves practised what they preached to schools about teaching all students well, they would have no need for secondary school results to pre-filter out those expected to fail tertiary studies.

If Progressive and Public educators in the form of teachers, schools, and teacher educators were able to take greater control of their domain, then it might well be possible to implement an approach to teaching mathematics that equips students with the kinds of mathematical tools they will need to function successfully as informed members of society, whatever their ultimate employment destination.

And so I arrive, by a circuitous route, back to the original aim of this thesis – that of helping mathematics teachers to become better at their jobs. But rather than improving teachers as I first set out to do, I have discovered that the job, not the teachers, is in the greatest need of improvement. Once school mathematics has been made teachable, then teachers will be better able to teach it.

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Appendix I: Initial teacher survey

MONASH University

TEACHER SURVEY 2007

All of your answers will be treated in strictest confidence. We are bound by the Monash University Human Research Ethics Committee to ensure that absolutely no information you provide can be relayed to anyone, including schools, principals and employers. You may withdraw from the process at any time and all data you have provided will be destroyed.

1. What is your name? ....

2. What is your gender? **M** **F**

3. What age group do you belong to? *(circle one)*

< 25 26 – 30 31 – 35 36 – 40 41 – 45 46 – 50 51 – 55 >55

4. How many years have you taught mathematics? *(circle one)*

1 2 3 4 5 6 7 8 9 10 10+

5. What is your highest level of formal mathematics education? *(circle one)*

Yr 10 Yr 11 Yr 12 1st Year Uni 2nd Year Uni 3rd Year Uni Post-Graduate

6. Which school would you recommend to a friend for their children to go to? Why?

....

....

....

....

....

....

7. What is your current employment situation? *(circle one)*

<12mth Contract 1 Year Contract 2 – 3 Year Contract 3+ Year Contract Permanent/Ongoing

Circle a number which best represents your responses to the following questions:

8. How likely is it for contract teachers to be retained at your?

0	1	2	3	4	5	6	7	8	9	10
Very Unlikely										Near Certainty

9. How important/relevant for students is mathematics compared to other subject areas?

0	1	2	3	4	5	6	7	8	9	10
Much Less Important/Relevant										Much More Important/Relevant

10. In teaching mathematics, how important do you think it is to make the curriculum personally relevant to students' lives?

0	1	2	3	4	5	6	7	8	9	10
Not Important At All										Much More Important

11. If a change to your teaching increased student understanding but also increased preparation times, how willing would you be to implement it?

0	1	2	3	4	5	6	7	8	9	10
Very Resistant										Very Keen

12. How valued do you feel at your school by your principal?

0	1	2	3	4	5	6	7	8	9	10
Totally Undervalued										Highly Valued

13. How valued do you feel at your school by your colleagues?

0	1	2	3	4	5	6	7	8	9	10
Totally Undervalued										Highly Valued

14. If a change to your teaching increased student understanding but increased assessment times, how willing would you be to implement it?

0	1	2	3	4	5	6	7	8	9	10
Very Resistant										Very Keen

15. How valued do you feel at your school by your students?

0	1	2	3	4	5	6	7	8	9	10
Totally Undervalued										Highly Valued

16. If a change to your teaching increased student understanding but increased noise levels in your classes, how willing would you be to implement it?

0	1	2	3	4	5	6	7	8	9	10
Very Resistant										Very Keen

17. How interested are you in pursuing promotion or positions of responsibility/leadership?

0	1	2	3	4	5	6	7	8	9	10
Totally Disinterested										Extremely Interested

18. How well respected are the leaders at your school by teachers generally?

0	1	2	3	4	5	6	7	8	9	10
No Respect										Highly Respected

19. If you have one, how much effort do you put into your annual review?

0	1	2	3	4	5	6	7	8	9	10
None										A Great Deal

We don't have formal reviews ☐

20. How long would you like to remain a classroom teacher?

0	1	2	3	4	5	6	7	8	9	10
I Want to Get Out Now!!										The Rest of my Working Life

Tick here if you would be willing to take part in an interview ☐

Tick here if you would be willing to take part in class observations ☐

Tick here if y

THANK YOU FOR YOUR TIME!!

Appendix II MONASH University

TEACHER WORK SURVEY 2009

1. On average, what time do you tend to arrive at school?

2. On average, what time do you tend to leave school?

3. On average, approximately how many hours of work do you do outside of school each week?

4. How do you know if you are doing a good job as a teacher?

5. Has there been any PD or other sources that have helped you to know how good a job you are doing? If so, in what ways?

When finished,
please fold here

6. What kind of things do you think makes someone a good teacher?

7. How good a teacher do you believe you are?

0 1 2 3 4 5 6 7 8 9 10

Terrible Superb

8. How good a maths teacher do you believe you are?

0 1 2 3 4 5 6 7 8 9 10

Terrible Superb

Appendix III: TTML observation rubric

Observer: ______________ Teacher: ______________ School: ____________ Date: __________ Title of task: ____________________

	Not evident	Partial	Progressing	Substantial	Comments
EXPLICIT LEARNING GOALS Focus of lesson and learning goals clearly explained.	No attempt made.	Some attempt made.	Moderately successful explanation.	Successful explanation.	
MAKING CONNECTIONS Explanations and tasks connect to previous learning. Emphasise 'how' and 'why'.	Little or no connection. Emphasis on 'how'.	Limited connection. Passing reference to 'why'.	Some connections. Emphasis on both how and why for some elements.	Strong emphasis on connections. Explanations of both how and why.	
STUDENT THINKING Students combine facts and ideas to synthesise, generalise, explain.	Routine practice.	At some point students engage in thinking.	One major activity in which students are expected to think.	Substantial opportunities for students to think.	
CHALLENGING TASKS Students have not been previously shown how to solve tasks.	No challenging tasks.	Tasks provide little challenge or demand for engagement.	A significant task is posed requiring engagement by students and some knowledge construction.	A challenging task is posed requiring sustained engagement. Students devise their own solutions.	
OPENNESS Tasks have multiple possible pathways.	No student choice of strategy or goal.	Teacher directs students on strategy and/or goal.	Teacher encourages students to choose their own strategy and/or goal.	Teacher encourages students to choose their own strategy and/or goal.	
MODES OF WORKING Forms of communication, criteria for success explained.	No attempt.	Ineffective attempt.	Good attempt.	Clear explanation.	

	Not evident	Partial	Progressing	Substantial	Comments
INCLUSIVITY Tasks and explanations made accessible. All students included.	Little attempt.	Some attempt.	Attempt, but not fully successful.	All students engage in task (adapted if necessary) and in discussion.	
APPLICATION AND TRANSFER Connections to practical application and transfer of knowledge to other contexts.	No attempt.	A reference to application. Little prompting of transfer.	Application suggested at times. Some attempt at prompting transfer.	Knowledge developed in context and transfer to other contexts is prompted.	
QUESTIONING Relevant, engaging questions. Building on responses.	Largely low level questions. Very little wait time.	A few challenging questions. Some wait time. Answers used in discussion.	Questions framed to engage and challenge students. Attempt to build on responses.	Questions engage, challenge students' thinking. Wait time appropriate. Active building on responses.	
TAKING OPPORTUNITIES Appropriate response to decision points in the lesson to enhance mathematical thinking and learning.	Opportunities rarely taken.	Some recognition and response to opportunities.	Most opportunities are recognised and response taken.	All opportunities are recognised and response taken.	
MAINTAINING THE CHALLENGE Encourage students to persist. Resist attempts to elicit instructions that will reduce demands of task.	No encouragement to persist. No opportunities to think.	Some encouragement to persist. Removes some opportunities to think.	Encourages students to persist, but offers some hints that reduce opportunities to think.	Encourages students to persist. Resists students' attempts to get directions.	
PULLING LESSON TOGETHER Pulling together key ideas on mathematical intent.	Little attempt.	Some attempt but unrelated to mathematical ideas.	Attempts made at various points in the lesson, with some success.	Building on student ideas, mathematical intent is made clear.	

Appendix IV: Initial TTML teacher survey

TTML
Task Types and Mathematics Learning

TEACHER SURVEY QUESTIONNAIRE 2007

All of your answers will be treated in strictest confidence. We are bound by the Monash University Human Research Ethics Committee to ensure that absolutely no information you provide can be relayed to anyone, including schools, principals and employers. You may withdraw from the process at any time and all data you have provided will be destroyed.

Part A: BACKGROUND TO TEACHING

A1. Your Name: ....

A2. School: ....

A3. School Phone Number: ....

A4. Email address: ....
(the one you use most regularly)

A5. Mobile: ....
(if you are willing)

A6. What year level(s) is the class(es) that you are
teaching as part of your involvement in the project? ....

A7. How many years
have you been teaching? : ....

A8. Not including 2007, how many years
have you taught mathematics at this level? ....

A9. List your qualifications:

....
....
....

A10. How much structured professional learning about mathematics teaching did you undertake in the last 12 months? (*tick one box*)

None ☐ A session or two ☐ About a day ☐ Many days ☐

Part B: BELIEFS AND CONFIDENCE IN MATHEMATICS TEACHING

Please circle the number best matching your response;

B1. Rate your knowledge of mathematics for teaching mathematics at this level

0	1	2	3	4	5	6	7	8	9	10
Poor										Excellent

B2. How confident do you feel in your teaching of mathematics at this level?

0	1	2	3	4	5	6	7	8	9	10
No confidence										Highly confident

B3. How confident do you feel in your ability to address the needs of learners who seem unmotivated in mathematics?

0	1	2	3	4	5	6	7	8	9	10
No confidence										Highly confident

B4. How confident do you feel in your ability to address the needs of students who experience difficulty in learning mathematics?

0	1	2	3	4	5	6	7	8	9	10
No confidence										Highly confident

B5. How confident do you feel in your ability to address the needs of very able learners of mathematics?

0	1	2	3	4	5	6	7	8	9	10
No confidence										Highly confident

B6. What aspects of your mathematics teaching do you feel you do well?

....

....

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....

....

....

B7. What aspects of your mathematics teaching would you like to improve?

....

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....

B8. Please tick (in question **B7.**) the aspects that you hope that this project will help you with.

Part C: PLANNING AND TEACHING MATHEMATICS

C1. How are the topics and sequence of topics for mathematics chosen at your school? (*Tick one*)

Someone else makes the plan and gives it to us ☐ The teachers decide together ☐ I decide for myself ☐

C2. Indicate how often the following describe how you plan your mathematics units of work

	Hardly Ever	Now and Again	Quite Often	Nearly Always
a. Make a list of interesting relevant activities and arrange them into the teaching sequence	1	2	3	4
b. Look at particular content goals (using VELS or similar) and work out how students might learn them	1	2	3	4
c. Follow the sequence in the textbook	1	2	3	4
d. Follow the sequence in the textbook but add in some other activities for variety and student interest	1	2	3	4

e. Write any other ways you plan your mathematics units here, and how often.

....

....

....

C3. Indicate how often the following describe how you plan your individual mathematics lessons

	Hardly Ever	Now and Again	Quite Often	Nearly Always
a. Make a list of interesting relevant activities and arrange them into the teaching sequence	1	2	3	4
b. Look at particular content goals (using VELS or similar) and work out how students might learn them	1	2	3	4
c. Follow the sequence in the textbook	1	2	3	4
d. Follow the sequence in the textbook but add in some other activities for variety and student interest	1	2	3	4

e. Write any other ways you plan your mathematics teaching here, and how often.

....

....

....

C4. Indicate how often the following stops you from teaching mathematics as well as you want to.

	Hardly Ever	Now and Again	Quite Often	Nearly Always
a. I don't have enough time to plan properly	1	2	3	4
b. The curriculum is too crowded	1	2	3	4
c. There are too many student in the class	1	2	3	4
d. There are too few useful resources available	1	2	3	4
e. As soon as the work gets difficult, the students give up	1	2	3	4
f. The students are not interested in learning	1	2	3	4
g. The students do not seem to remember anything	1	2	3	4
h. The students did not learn the work in previous years	1	2	3	4
i. The spread of abilities is large	1	2	3	4
j. Frequent interruptions to the regular program	1	2	3	4
k. Student absences	1	2	3	4

l. Write any other restrictions on your mathematics teaching here and how often they interfere.

....

....

C5. On average, how long do you anticipate spending on planning each maths lesson? (tick one box)

< 10 mins ☐ 10 to 20 mins ☐ 20–30 mins ☐ > 30 mins ☐

C6. The following is a description of an idea that might be used as the basis of a lesson.

Which is bigger, $\frac{2}{3}$ *or* $\frac{201}{301}$ *?*

a. If you developed a lesson based on this idea, what mathematics would you hope the students would learn?

....

....

....

....

b. Describe, briefly, a lesson you might teach based on this idea

....

....

....

....

....

....

....

c. What might make teaching this lesson difficult?

....

....

....

d. How would you gauge if the lesson was successful?

....

....

....

C7. In what percentage of your lessons could the main activity be described as something like the following: (*rough estimates are fine, but they should add to 100%*)

	%
a. I give a planned explanation of a new skill or concept, the students work on examples, we correct their work together (e.g., Showing how to find the area of a circle.)	
b. I use an interesting model or technique that illustrates a mathematical principle, and the students work on activities associated with the use of the model or technique (e.g., Showing how the area of a circle is less than four square radiuses.)	
c. The class works on interdisciplinary tasks, involving mathematics and some other curriculum area as well, and the students write a report (e.g., Graphing a character's movement in a novel, or working out relative prices of items in Ancient Civilizations.)	
d. A non-mathematical realistic context (e.g., sport, cars, shopping) is used to illustrate a mathematics concept, and students work on problem(s) based on the context.	
e. I pose an open-ended problem, or investigation, and the students work on the problem, with class discussion and teaching at the end of the lesson (e.g., For a given perimeter of a rectangle, what might be the area?)	
f. The students play a game that illustrates some mathematical concept, then we discuss the mathematics concepts included in the game (e.g., Prizes for certain dice roll combinations.)	
g. The students do worksheets practising skills or procedures that they have learned previously.	
h. Students move around the school to collect data or engage in some outside activity to help understand and explore mathematics concepts.	

i. If there are other important ways you structure your mathematics lessons, please write a description of what you do and what percentage of your lessons would be spent on it.

....

....

....

....

....

Part D: CHARACTERISTICS OF THE STUDENTS

D1. In your experience, what percentage of your mathematics students could be described as the following?
(*each line is independent of the others and don't need to add to 100%*)

	%
a. They seek success but only on tasks with which they are familiar	
b. They associate getting smarter with trying harder	
c. They avoid or give up quickly on challenging tasks	
d. They discourage each other from trying too hard or appearing to be too smart	
e. They connect effort with success and take pride in successful effort	
f. When experiencing difficulties, they seem to lose confidence in themselves	
g. They seem to believe they are as intelligent now as they will ever get	
h. They remain focused on learning skills even when challenged	
i. They are self motivated to learn	
j. They try to do their best at mathematics	
k. They plan out how they will tackle maths problems	
l. They connect trying hard now to increasing their opportunities in the future	
m. They learn from their mistakes	
n. They contribute to class discussions	
o. They listen when they should be listening	
p. They prefer mathematics to be realistic	
q. They always, or nearly always, do their homework	

D2a. Pick the year level which you teach most for mathematics, write it here .... and complete the table below for this one year level

The following are some extracts from the Mathematics Progression Points for Level 3/4. What percentage of your students do you think could do these well …

	… at start of this year (%)	**… at end of this year (%)**
b. Students use decimals, ratios and percentages to find equivalent representations of common fractions (e.g., $\frac{3}{4}=\frac{9}{12}=0.75=75\%=3:4=6:8$).		
c. They add, subtract, and multiply fractions and decimals (to two decimal places) and apply these operations in practical contexts, including the use of money.		
d. They divide fractions using multiplication by the inverse		

THANK YOU FOR YOUR TIME