# An Investigation of Pre-service Secondary Mathematics Teachers' Beliefs as They Begin Their Teacher Training

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Research suggests that pre-service teachers' beliefs about mathematics and mathematics teaching are a strong indicator of their future teaching practice. In this interview study, 16 pre-service secondary teachers were asked to reflect on their own school experiences and discuss their beliefs about what constitutes a good teacher and good teaching. Results indicate that pre-service teachers enter their teacher training with fixed views about mathematics instruction that are based largely on interpretations of how their own mathematics teachers taught the subject to them.

While many mathematics teacher education courses are mainly concerned with content knowledge and pedagogical knowledge, there is considerable research on the beliefs held by pre-service teachers and the conflict between the course learning theories and the beliefs that pre-service teachers bring to the course. This paper reports on the early stages of a project where we will follow a group of Graduate Diploma of Education (Grad Dip) students in two universities in order to investigate pre-service secondary teachers' beliefs about mathematics and mathematics teaching as they progress through their university studies and move into schools, both during the practicum experience and in their first year of teaching.

## Teachers' beliefs

There is much evidence in the literature in mathematics education that teachers see mathematics as a fixed and sequential body of knowledge that is most effectively learned by rote, algorithmic and repetitive procedures (Nyaumwe, 2004; Schuck & Foley, 1999). There is a consequent emphasis on instrumental learning rather than relational (Skemp, 1976) resulting in

- mathematics curricula driven by computational skill as the major goal;
- mathematical knowledge as rule bound and unconnected;
- teaching as telling and learning as memorising (Even & Lappan, 1994).

Ball (1990) found that many teachers believe that mathematics is a collection of discrete bits of procedural knowledge that are rarely connected and therefore requires innate ability. There is a close relationship between beliefs about mathematics and classroom practice (Nisbet & Warren, 2000) and teachers' beliefs are often strongly-held and notoriously difficult to change (Wilson & Cooney, 2000).Therefore, it may be difficult for teachers to adopt practices such as a problem solving approach where students construct mathematical ideas for themselves, that depart significantly from those which they experienced as learners (Szydlik, Szydlik, & Benson, 2003).

## Pre-service teachers' beliefs about "good" teaching

Pre-service teachers draw on their own experiences as students in mathematics classrooms to describe 'good' teaching (Borko et al., 1992; Cooney, Shealy, & Arvold, 1998). It is not surprising then that pre-service secondary teachers look on the mathematics

teaching they received during their own education as the "correct" way that mathematics should be taught — after all it was successful for them. A natural consequence of this thinking is that the style of teaching that was appropriate (successful) for them will be appropriate (successful) when they implement it in their own classes (Frykholm, 1999). On the other hand, students' memories of their education may not always be accurate (Ellsworth & Buss, 2000) but what they remember influences their thinking about what constitutes good teaching.

Weinstein (1990), Brookhart and Freeman (1992) and others found that pre-service elementary teachers saw good teaching largely in terms of the affective domain. They wanted to relate to pupils as equals and have the students like them. Weinstein found that the pre-service teachers most frequently saw themselves in a parenting or nurturing role (58%), but also saw being able to relate to children (39%), maintain discipline (37%) and motivate students (34%) as being important. While the ability to give clear explanations was also seen as an important characteristic of a good teacher (26%), fewer participants (21%) saw knowledge of subject matter as important. Weinstein suggested that these beliefs support the view that a teacher is born not made (which of course minimises the role of a teacher education program).

Pre-service mathematics teachers often believe that good knowledge of their subject is necessary to be a good teacher (Brookhart & Freeman, 1992) and that the mathematics is easy (Ball, 1990) but, when asked to explain concepts, they also admit that they "do it by rote". Ball (1990) and Foss and Kleinsasser (1996) found pre-service teachers focus on rules and procedures to be memorised to the point where mathematical explanations become restatements of the rule. This simplistic view that teaching is all about telling and explaining facts links with the idea that "teachers teach and students learn" (Brookhart & Freeman, 1992).

Such beliefs about the nature of mathematics teaching are difficult to shift (Brown & Borko, 1992; Cooney et al., 1998) and most research has shown that these beliefs seldom change during teacher education courses (Foss & Kleinsasser, 1996; Kagan, 1992). If a pre-service teacher's beliefs are at odds with the underlying philosophy of the course, then it is unlikely that any change will occur (Bright & Vacc, 1994) and such a situation may even result in initial biases becoming stronger (Szydlik et al., 2003). Therefore, it is important to understand not only what teachers believe, but also how their beliefs are structured and held (Cooney et al., 1998).

Posner, Strike, Hewson and Gertzog (1982) suggested that for existing beliefs to be replaced, the new belief must intelligible and appear plausible. If students cannot see a reason to change, they often alter the new idea to fit their original long-held beliefs. Ball (1990) concluded that these beliefs not only shape how pre-service teachers teach but also how they approach learning to teach. Therefore, most of what happens in pre-service courses should challenge pre-service teachers' views of mathematics so they become open to the more collaborative, creative discipline that is mathematics today (Even & Lappan, 1994).

Much of the research described here has examined the beliefs of pre-service primary teachers and we have found relatively few studies of pre-service secondary mathematics teachers. Even so, the research on primary does provide a useful starting point for any discussion of pre-service secondary teachers' beliefs (Frykholm, 1999) and we hope that our own research helps to redress the imbalance in the literature.

## Method

The Graduate Diploma of Education (Grad Dip) at Macquarie University and the University of Technology, Sydney (UTS), is available to graduates with academic qualifications in their chosen subject area. It is a one-year, full-time equivalent, professional qualification for secondary teaching comprising units in education, curriculum, methodology and supervised professional experience. Typically, the students who apply for the Grad Dip are mature-aged and have decided to train as mathematics teachers after previous workplace experience.

All of the applicants for the Grad Dip at Macquarie and UTS were invited to participate in the research project. A random sample of 16 pre-service teachers (8 from each institution) was subsequently taken from those applicants who had accepted a place in the Grad Dip at their chosen institution and returned a signed consent form.

Each pre-service teacher was interviewed individually for approximately 20 minutes, either immediately prior to the commencement of the university program or during the first week of classes. The interviews were semi-structured and designed to investigate the pre-service teachers' memories of their time as school students, their beliefs about the teaching of mathematics, and their reasons for undertaking training as a mathematics teacher. All of the interviews were recorded and transcribed for later analysis of recurring themes.

## Results

The pre-service teachers generally had little difficulty in recounting their own school experiences and using them to describe some of what they held to be the crucial elements of good mathematics teachers and teaching. Although their specific memories of a particular classroom or teacher may not be entirely accurate, what they chose to remember and how they described the person or incident can be regarded as important indicators of their beliefs about mathematical teaching and learning.

### *Memories of School*

The first part of the interview dealt with the pre-service teachers' recollections about the people and events from their student days. Even though primary school was long ago for the participants and their memories of that time were rather sketchy, many were able to recall a feeling of mastery of the work they were doing. This was expressed in terms of their ability to learn new concepts easily, feelings of boredom because of what they regarded as unchallenging exercises, and finishing the work much faster than their peers. Similar themes emerged in the discussions about secondary school, but the characters and events became more sharply focused.

Typically, the participants recounted a very traditional classroom environment where the teacher was the authority figure, both in terms of maintaining a tight rein on student behaviour and as the font of all mathematical knowledge. The descriptions of lessons were remarkably consistent across the entire group, regardless of age, gender, or whether they had attended secondary school in Australia or overseas.

> We used to sit in pairs, in sort of rows. We had a standard textbook, he would give, you know, go through a particular process up on the board and then we would do exercises from the texts.

The interviewees reported that they achieved good results in mathematics and were placed in the higher-ability classes. They described lessons that ran in an orderly fashion

where students sat quietly and completed their work. Although some thought the approach straightforward and unimaginative, they were generally pleased with it and responded well to mathematics at high school.

> I don't remember doing a lot of group work at all, but I guess I respond quite well to that sort of standard learning environment anyway, so it wasn't ever a problem for me.

The participants expressed a sense of admiration for their mathematics teachers, particularly the teachers' affective characteristics. In particular, good teachers were caring and approachable people to whom students could turn when they need further help to understand their work. The best teachers were also passionate about mathematics and shared their broad knowledge and love of the subject in a way that inspired many of the pre-service teachers to further their mathematical studies. These teachers were also dedicated to their students and would make themselves available outside of lessons for consultation.

The ability to explain mathematical concepts clearly and succinctly was another important trait of good mathematics teachers. For the interviewees, these lucid explanations were grounded in the teachers' thorough knowledge of the subject matter and facilitated by good classroom control which afforded everyone an opportunity to hear what the teacher was saying and absorb it without distraction. Good teachers were also well organised so that if someone failed to grasp an idea after the initial explanation, the teacher was able to draw on other instructional strategies to assist the student.

### *Good Lessons*

Many of the elements of good mathematics lessons described by the participants reflected their own experiences, both at school and in their university mathematics courses. In varying degrees, they all outlined a lesson structure characterised by careful explanations of well chosen examples from the teacher followed by the completion of "hundreds" of graded exercises by the students in order to practise their skills.

> You have to develop a good set of definitions. The definitions have to be very clear and then you develop some theorems, some proof at the level the students, allow the proof to be understood, or some critical examples, not just any example. You then have a selection of exercises, which have an increasing degree of difficulty.

The descriptions of good lessons concentrated on the teacher as the explainer of concepts and class controller. The role of drill and practice was highlighted by many who saw the mastery of basic skills as crucial to the development of mathematical understanding. It was the role of the teacher to pitch the explanations at just the right level so that the students would be challenged but not become bored or distracted.

The interview participants often projected their self-images as students onto the role they hoped that pupils should play in good lessons and there was an underlying expectation that all pupils would act in a similar manner to the way that the pre-service teachers had behaved when they were at school. In other words, students were expected to be highly motivated and enjoy completing numerous exercises, remaining focused and attentive at all times.

> A good maths class, to me, is a class that understands what's going on and likes it. They're well behaved; motivated to complete their work in that area even in their own time. That's how I was when I was in my late secondary school years.

Another aspect of good lessons mentioned by many of the interviewees was the need

to make the mathematics relevant to students. This most commonly required the teacher to choose examples from the real world and present these to students as a way of maintaining their interest. It also involved showing students how the mathematical concepts they were learning would be useful to them in later life, though there was a sense among the group that this would be more difficult in topics such as algebra which were regarded as highly abstract. In order to expose further some of their thinking on the role of realistic examples, some of the participants were asked about how they might teach an introductory lesson on differential calculus and, here too, there were echoes from their own experiences as students and as tutors. For some, the need to make learning more meaningful was born out of dissatisfaction with their own schooling.

> I didn't like learning calculus because it was all so theoretical and I wanted to know what we were trying to achieve, like why do we take the power minus one, and so on. What's the point? So I think it's good to say, "This is why we do derivatives."

For another person, trying to help his daughter with her homework started him thinking about the need to develop understanding in students.

> Well, what I noted with my daughter is that it's just a problem on a page and she still doesn't get the notion that a differential, well it's all about movement and, you know, acceleration and velocity and changes. … Perhaps you could show this for calculus, so the students just don't see it as depressing, you know, a set of exercises in a book. It has to be got through, but has some relevance to the outside world, you know, it may be the way they drive a car or kick a ball and so on. So I would try and relate it to real world things.

There is a sense in both of these comments that while there are no shortcuts and mathematics is still about rules that must be learned and practice exercises that have to be completed, the teacher can make the process more meaningful and enjoyable by the kinds of examples and explanations that are used.

### *Becoming a Teacher*

The interviews explored why the participants had decided to embark on the road to mathematics teaching and what kind of teacher they hoped they would become. The student teachers regarded mathematics as an important subject because it developed one's logical thinking skills and was the basis for so many other important human endeavours. They had enjoyed mathematics at school and saw first-hand the powerful effect that teachers could sometimes have as role models for their students. They were full of enthusiasm for the task of sharing their love of the subject with their students and helping them to see the importance of mathematics in their lives. Some expressed high ideals such as wanting to inspire their students and make a positive change in young lives.

All of the participants expressed confidence in their own mathematical ability and commented that they possessed sufficient knowledge to teach the subject effectively. Many had been employed in positions as instructors of one kind or another, or worked specifically as mathematics tutors, and they reported that they had enjoyed this work and were pleased with the positive feedback they had received from students, colleagues and family members. There was also something about the nature of mathematics as logical and what was referred to as "very black and white" that seemed to appeal to some of the personalities in the group.

When describing the kind of teacher they wanted to become, the interviewees focused again on the personal qualities of the best of their own teachers. They emphasised the affective domain rather than launching into discussions about teachers' content and

pedagogical knowledge, which is perhaps not surprising since they had not yet begun to think seriously about how mathematics might be taught.

> I probably would like to be looked at as being an approachable teacher, someone that would, that the students can come to if they do have problems and not feel intimidated or feel, you know, that they're being condescending or anything like that so they don't feel belittled.

The pre-service teachers wanted to be respected by their students and known as someone who made learning interesting and fun so that the class would be excited about mathematics and see it as relevant to their daily lives. This approach also seems to reflect the pre-service teachers' own attitudes to learning mathematics and fails to take account of the fact that many students do not respond as favourably to the direct instruction methods they had experienced. They appear to have led somewhat "sheltered lives" among the brightest students in the top mathematics classes where traditional teaching approaches were met with less resistance and may have even had some appeal.

The interview participants were also asked to comment on any concerns they had about becoming a mathematics teacher. The dominant issue for many was that of classroom management and they expressed doubts about how they could successfully maintain order during lessons. Although they were unlikely to observe unruly mathematics classes when they were at school, some had heard more recent stories about difficult students who were verbally and sometimes physically aggressive to their peers and their teachers and they were apprehensive about the reports. They saw poor student behaviour as closely related to lack of interest and the difficulties in relating some more abstract concepts to real life, but they felt that if they could do so then they would be better able to keep students in check.

## Discussion and Further Research

The interviews we conducted with pre-service teachers indicate that most arrive for their teacher training with firm views about the nature of mathematics and how it should be taught. In large part, they base their ideas on personal experiences of learning mathematics at school and the classroom practices they observed from their favourite teachers. However, these classroom experiences are always viewed through the lens of the *student* rather than the *teacher* and while the participants were able to articulate clear ideas about how mathematics is best learned, they were not quite as forthcoming about how it should be taught and tended to frame their comments from the student's standpoint. When describing learning, they emphasised the need for well chosen examples, graded exercises, and the use of textbooks for drill and practice. When describing teaching, they referred to the need for clear explanations (so that students could develop their understanding), real-life examples (so that students could see the relevance of their mathematics) and classroom control (so that students could concentrate on their learning). They also focused largely on the affective factors associated with good teaching such as approachability, passion, a caring attitude and dedication.

One of the pre-service teachers reported experiences which could be regarded as student-centred as he described a Year 8 teacher who included practical activities and investigations in his lessons. This pre-service teacher described a good mathematics lesson as one which would "have lots of student activities, engaging the students in practical activities to try to link the concepts to the real world" and contrasted this with unsatisfactory lessons where "the teacher is sitting out the front assigning exercises and

just letting the students do the exercises and maybe doing a few examples on the board without really engaging the students". However, when asked how she might teach a lesson on decimals, she responded,

> I'd start with the concepts, I guess. So I'd write up a heading on the board say, for example, adding decimals and I'd write the theory behind it. You know, you need to put the point above the point and then I'd run through some examples. But I would make sure the examples would have a real-life context to it like money examples and money problems. And then I would just continue on with the other theory.

This vignette shows just how difficult it can be to effect change in pre-service teachers' attitudes. Limited personal experience of a more student-centred approach is a useful but insufficient ingredient in ensuring that pre-service teachers examine their often deeply rooted views about teaching and learning mathematics.

We hope to identify other factors that might assist pre-service secondary teachers to reflect critically on their beliefs and adopt a more constructivist pedagogy. We plan follow-up interviews throughout the year as the group complete their Grad Dip program. In particular, we hope to investigate how they interpret their practicum experience and relate it to the ideas they are exposed to in their university course so that we can document the extent to which those experiences shape their beliefs about mathematics teaching. We will also continue to follow them into their first year of teaching and examine how their beliefs are played out in the classroom.

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