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ABSTRACT

This self-study of teacher education practices examined student teachers' and teacher educators' beliefs regarding the learning and teaching of mathematics. Data collection included questions from students about mathematics education issues in which they were interested; other students' responses to those questions; a questionnaire examining emerging themes from their questions and responses; interviews with eight students; and interviews with mathematics educators. Results showed that student teachers often held beliefs about mathematics and learning that constrained their access to rich and powerful ways of learning. Examination of the teacher educator's new practices also revealed obstacles to reform. The teacher educator appeared to be driving a mathematics reform with unwilling passengers. She realized that her task was to make students aware of their beliefs and the implications of these beliefs for teaching and learning. She created an intervention, though many students considered it insufficient to overturn years of experience. She worked to make the subject matter more explicitly linked to the school curriculum content. She received funding to use a computer web-based program to encourage debate about the nature of mathematics and help students consider their beliefs about mathematics teaching and learning. Survey results indicated that the computer intervention changed students' views of mathematics and mathematics education. Deep, ongoing self-study of teacher education practices is essential if teacher educators are to be the leaders of reform practices. (Contains 23 references). (SM)

# DRIVING A MATHEMATICS EDUCATION REFORM WITH UNWILLING PASSENGERS.



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# DRIVING A MATHEMATICS EDUCATION REFORM WITH UNWILLING PASSENGERS

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As a teacher educator continually trying to improve my own practice I have engaged in self-study for many years. However, I have come to think about self-study in different ways as I have become involved in the reform movement in mathematics teaching and learning. It has become clear to me that self-study not only has the aim of improving personal practice but also of contributing to the reform of teacher education practices in general. Serious self-study must take the context of the practice and its cultural implications into account.

In my self-study of teacher education practices I discovered that it was essential for me to be familiar with my students' beliefs as well as my own. I found that prospective elementary school teachers often held beliefs about mathematics teaching and learning that constrained their access to rich and powerful ways of learning. My practices consequently needed to be revised to help students challenge these beliefs. However, careful study of my new practices also revealed obstacles on the road to reform. I appeared to be driving a mathematics reform with unwilling passengers.

By continuously studying my own practices as a teacher educator I have become aware of several pitfalls and opportunities for helping my students to see mathematics as a dynamic, accessible and connected subject. However, I acknowledge that the road to reform in mathematics teacher education is difficult and circuitous, given the obstructions of students' prior experiences and beliefs and the detours necessary to avoid these obstructions.

Self-study of teacher education practices is steadily increasing in importance. However, the nature of self-study is still quite difficult to define and is seen as covering a range of purposes from reflective inquiry into one's own practice to more formal research meant for a wider audience (Barnes, 1998). This paper deals with my journey of self-study over the last 14 years as I started initially to seek validation of my existing theories about learning and teaching mathematics through reflective inquiry, and later found that these theories were

being challenged through a deeper and more formal investigation of my practices. My paper suggests that reflective inquiry on its own is not sufficiently extensive to capture all the implications of particular practices, but that a deep understanding of the context in which the practice occurs is essential for self-study of teacher education practices to contribute to reform in teacher education.

The story of my study of my own practices and theories is appropriately placed into this symposium about the obstructions, detours and ringroads along the road to reform. This symposium deals with the conflicts of opposing paradigms in a number of different discipline areas within a particular context. Each of the presenters has experienced the tensions of personally held paradigms meeting the roadblocks of others' paradigms. Our papers tell the stories of these clashes.

For me, it is interesting that the clash of paradigms that I have been experiencing personally in the development of my own theories of learning and teaching mathematics, reflects to some degree the large-scale clash of paradigms being presently experienced, particularly in the United States, in the so-called Math Wars, where those engaged in implementing reforms in mathematics education (for example, the National Council of Teachers of Mathematics (NCTM)) are engaged in heated debates with others, who feel that the reform movement is impeding the development of mathematical knowledge for many (for example, the Mathematically Correct Society). While the NCTM encourages teaching in ways, and using content, that are accessible to more people, other groups call for a return to the development of basic skills in the use of algorithms and procedures, and more teacher-centred methods of teaching.

My paper traces my development as a teacher educator in mathematics education. It discusses the limitations of self-study without recognition of the broader picture of the context. The changes in my practices which occurred due to deeper self-study are discussed and the implications of those practices are considered. I suggest some routes that may be useful in the reform of mathematics education practices and in the self-study of such practices.

**Teaching as telling: the driver in control**

My story started approximately 14 years ago when I first started teaching in a teacher education program, having moved from teaching in a secondary school to teaching in a tertiary education institution.

Mathematics education was then, as it is now, my passion. I believed, and still believe, in the right of **every** person to have successful and fruitful experiences in mathematics education, at least up to the end of secondary schooling. I felt that the understanding of concepts underpinning much of mathematics was essential, as a first step in the appropriate and efficient use of algorithms and processes. However, I had at that point in time, a belief in the role of the teacher as the expert, clearly explaining concepts to others and managing a very teacher-directed class. As teaching mathematics in ways that were accessible to all was a founding principle of my thinking and approaches, I evaluated my students' learning carefully by assessing whether they had achieved the cognitive outcomes I desired through assessment tasks, and by asking them to evaluate my teaching through surveys developed by our university's Centre for Learning and Teaching. My methods of evaluating my teaching were consistent with my assumptions about teaching as telling.

It appeared that most students were very successful in achieving my desired outcomes and that these outcomes were also seen as desirable to them. The student evaluations were extremely positive, giving me scores well above the faculty, and indeed university averages, for each aspect of my teaching. As I was experiencing no conflict between my theories of learning and teaching and students' reactions to them, I continued teaching in this manner for a number of years.

**Researching my own practice**

Self-study of teacher education practices involves the examination of a person's practice for purposes of improving that practice. However, this purpose is not the only reason for self-study. The other purpose is to develop deeper understandings about teacher education in general; to produce and advance the knowledge about teacher education (Friesen, 1997). I believe that in focusing only on my practice in the above stage of my teaching, I neglected to consider the contextual and theoretical implications of my practice. While acting as a "good practising teacher" I did not see my role as a "scholar teacher" (Turney and Taylor, 1996) or researcher. It was only with the support and encouragement of my head of school, Professor

Chris Deer, that I began to see my role as a teacher could be enhanced by my research and self-study of teacher education practices (see Deer, 1999).

I began doctoral studies and the process of research and the results of these studies led to a crossroads in my beliefs about teaching and learning mathematics. The process of undertaking a deep research study, with its corresponding emphasis on a thorough understanding of the relevant literature, acted as a catalyst for me in the process of asking questions about my teaching. I started asking different and deeper questions about my practices. The literature suggested new ways of teaching to me. It also discussed the consequences of transmissive teaching. My research methodology allowed me to probe students' beliefs in much richer ways than the evaluative surveys used previously. I gained new and different insights into student beliefs.

**The study: Reading the route map, examining the landmarks and signposts**

My research investigated the beliefs and attitudes of prospective elementary school teachers with respect to their learning and teaching of mathematics (Schuck, 1996). Half the first year student cohort (50 students) were participants in the study. Data collected were:

- questions that students had posed about issues in mathematics education in which they were interested,
- responses by other students to those questions,
- a questionnaire in which I further developed emerging themes from their questions and responses,
- in-depth interviews with eight of the students
- in-depth interviews with the mathematics educators. These interviews included one I conducted with myself. I posed the set of questions I had developed and recorded my answers.

My findings, which certainly corresponded with other researchers' findings of the time (for example, Ball, 1988, 1990; Foss and Kleinsasser, 1995, 1996), were that prospective teachers' beliefs about teaching and learning mathematics were major inhibitors of their own learning and of their ability or desire to facilitate the learning of others in the mathematical area. Prospective elementary teachers often believed that you had to have a "mathematics brain" (Schuck, 1996) to be able to do mathematics, and that "mathematics wasn't for people

like us, it was for the smart students" (Schuck, 1996). They also had clear and strongly held ideas about how to be taught; a good teacher explained clearly and gave opportunities for a great deal of practice; similar beliefs to those I had held previously. The strong emphasis on teaching as telling did not allow for much flexibility in methods of teaching or for idiosyncratic ways of solving problems (Schuck, 1996).

The students' beliefs about the teaching of mathematics directly challenged my theories of learning and teaching in that our (shared) ways of teaching seemed to obstruct ideas of access for all, and of learning as a personal and idiosyncratic process, dependent on past experiences and contexts. Further study and investigation of the theory of learning espoused by constructivists (Ernest, 1991; and others) directly challenged my previously held views and led me to develop new personal theories of learning and teaching which acknowledged that learning was not transmissive but an active process by the learner. As I studied the literature, I saw the power of the community for learning. I came to believe that learning was very much a socio-cultural activity (Cobb, 1994; Dengate and Lerman, 1995) in which the context and the interaction of others were major influences in any one person's learning (see also Walker, 1999).

It consequently became apparent to me that my task as a mathematics educator was to help students become aware of their beliefs and the implications of these beliefs for their teaching and learning. I saw that teaching as telling, while comfortable, confirmed students' existing beliefs about mathematics education, and did not encourage change in their thinking. I became convinced of the value of participatory learning in which students were encouraged to take more control of their own learning. I developed an intervention (Schuck, 1997) in which I encouraged students to think as researchers, examining their own beliefs and reflecting on the consequences. I began teaching mathematics content in participatory and investigative ways - by setting up rich environments in which students could investigate, debate and justify their reasoning to one another. I introduced new topics into the curriculum for the elementary student teachers, which were suggested by the National Council of Teachers of Mathematics (1989) as accessible topics, useful for demonstrating the nature of mathematics. My practice involved very little telling or lecturing. Students carried out tasks, and then explained to each other how they had reached various conclusions. Historical and social aspects of mathematics were emphasised as were different approaches to learning.

Evaluations of such ways of teaching were mixed. Most students acknowledged that these methods were beneficial and that they wished they had been taught in these ways while at school. However, a few of the students suggested that such methods were not appropriate for them at this stage of their learning, and that they benefited far more from exposition and clear indications of how to conduct particular lessons. Indeed I had neglected to take account of the power of their life histories. Like me, students had gone through a school system in which they had been taught in transmissive ways – they had developed a vision of teaching and learning that was based on their experiences (see also Segal, 1999). Unlike me, they had not had the opportunity to think deeply about their views or see the implications of their beliefs in the context of mathematics education reform. For these students, the intervention they experienced in my class was not sufficient to overturn years of experience.

Many students felt that it was inappropriate to learn about the cultural context of learning in mathematics as they felt that this was not directly related to the knowledge they needed to teach in an elementary school. If content matter was not explicitly and directly related to the mathematics taught in the elementary school, students dismissed it as irrelevant (Schuck, 1996). These views were reinforced by experiences in elementary classrooms. When student teachers brought their new found learning to the classrooms in which they were placed for field-experiences, their school-based teacher educators often were dismissive of their learning. These teachers would suggest that authentic learning, seen by them as the learning that took place in schools, was very much of the sort I too had practised previously - of teaching as telling and clear exposition followed by drill and practice, and of content from a syllabus that was traditional in manner.

> *...we were actually doing all the Egyptian [numeration system] and everything when we went out on our first prac and I thought this will be terrific you know, we really can tell the children all about the history of mathematics and they can understand it all more and they can get really excited about it too.*
>
> *And of course, the teacher said "Oh, are you doing that rubbish? That's just absolutely ludicrous, you know. We'll get on with this, there's too much to cover in the curriculum without all that" and so that was squelched...*
>
> *That reinforces something in my mind, it reinforces that what we're doing at university is so totally unrelated to what happens in*

*reality in schools, where do you tie them both in? That's what it reinforces.* (Gail, student teacher)

Through my self-study, which involved carefully reading what students had written about the subject and about their beliefs, I became aware that I needed to make the subject matter more explicitly linked to the content of the school curriculum. The students' strong vocational orientations were often their major motivations for studying in our program. If they felt the subject matter would achieve their vocational aims, they were motivated to study it. Recognising that this vocational orientation was the driving force for many of the students allowed me to modify the subject matter so that it would be more relevant for them. However, the student input also alerted me to a disturbing realisation that embracing socio-cultural or constructivist theories of learning often meant that the importance of subject content knowledge was substantially downgraded in students' thinking.

**If the journey is enjoyable, the destination is unimportant**

It has been noted in the literature that for many teacher educators involved in reform of teacher education, the desire to challenge students' beliefs about learning and teaching, and to shift these beliefs away from transmissive models and towards constructed models, may be responsible for a downgrading of the value of subject matter knowledge in these programs (Floden, McDiarmid and Wiemers, 1990). In the case of mathematics education in our program, the majority of teacher educators involved in the program believed that it was important to shift students' thinking. However, none of them (including myself) believed that the subject content knowledge was of lesser importance. Nevertheless, it appeared that students, being acutely aware of their own struggles with the content matter of mathematics, were relieved to learn about theories in which the role of the teacher is not that of an expert but rather of a facilitator who learns with the students in the classroom. Students saw the implications of this type of role as being that teachers did not have to be very knowledgeable about subject content matter provided they were enthusiastic, empathetic and supportive.

While the latter qualities for a teacher were emphasised in our teaching, the teacher educators involved in the development of mathematics education programs for the student teachers all (myself included) strongly believed that students needed to understand the conceptual underpinnings of any mathematics they were going to be teaching to future students. I found Shulman's framework (1986) of a number of different content knowledge categories very

useful in the development of my theories about teaching and learning. These content knowledge categories included:

- pedagogical content knowledge, or knowledge of the content that is most appropriate for children to learn, knowledge of which avenues are fruitful to explore and what aspects of the subject matter tend to be problematic
- subject matter knowledge or knowledge about the actual subject matter, including understanding the underlying structures and concepts of the subject
- curricular knowledge or knowledge of what comprises the curriculum and what materials are associated with curricular knowledge as well as other knowledge about the curriculum.

However, in researching my practice with my students, I did not find evidence of a shared valuing of all these categories of content knowledge. Rather, I found that the emphasis on empathy and nurturing completely overshadowed many students' belief in the importance of subject content knowledge. In fact, some students indicated that they felt it was a disadvantage to be knowledgable about mathematics as this expertise would prevent them from understanding their students' struggles with the material being taught.

> *I know just from personal experience I don't ... because of my lack of knowledge I don't get agro [aggressive/angry] if they don't get it right. I can sit down for hours and help them work a sum out and show the different ways of working it out without losing my temper, because I don't have this ... baggage of extra knowledge on me. Because I didn't have this knowledge, is why I was told I was stupid. "You should know how to do it, you're an idiot." But I didn't have the knowledge to do it ... so you know, I think it's an extra plus that I've got, to take into a classroom.* (Pip, student teacher).

Pip sees her lack of knowledge as an advantage to her teaching, because it will make her more patient and sympathetic if her students struggle to understand. Rene shares Pip's view about lack of understanding being an advantage in teaching:

> *I feel that my lack of understanding in particular areas at primary school will aid my teaching of that area. For example I will have a better knowledge of teaching fractions and of its practical applications. This will enable me to understand and react appropriately to the problem the students may have.* (Rene, student teacher)

So lack of understanding is suggested by Rene as an advantage to her teaching.

My self- study of teacher education practices had led to a conflict between the theories of learning and teaching which I espoused and held. On the one hand I believed that prospective teachers were obliged to make mathematics accessible to all their future students, and that methods of participation, collaboration and investigation were highly appropriate for enhancing this access. On the other hand, I felt that it was extremely important for student teachers to have a strong understanding of the concepts underlying any of the activities they developed for school students, and a grasp of the methods and nature of mathematical endeavours. While continuing to believe that students' beliefs about mathematics and mathematics teaching and learning needed to be made explicit and that students should be given the opportunities to examine these beliefs and consider their implications, I also became aware of the need to emphasise the importance of subject content knowledge as suggested by Shulman. However, my belief about the importance of subject content knowledge often led to a collision with my belief that students should be able to learn mathematics in a way that is anxiety free and interesting. Students did not enjoy engaging with the mathematics content and an insistence on the value of content knowledge often led to a reversion in their attitudes towards mathematics.

To me, this dilemma is a case study of the conflict in mathematics education occurring today. My way of resolving it has been to ensure that the subject content matter we deal with in classes is both highly relevant to the teaching of elementary mathematics and also accessible to all students. To an extent, this has led to disagreement with some of my colleagues who believe that we should ensure a higher level of understanding of mathematical content. It is my belief that having an understanding of elementary school mathematics and an interest and confidence to investigate further will be more beneficial in developing mathematical understanding in the long run. As teachers, my students will learn more mathematics as they need it: but only if they have the confidence to pursue this knowledge rather than avoid it. Meanwhile, I continue to strive to both challenge my students' beliefs about mathematics and to engage them in developing their understandings of the content. Using information technology has proved to be a useful way of achieving these aims.

**Technological advances**

With the rapid development of information technology, many universities considered ways in which they could use such advances to make their program offerings more competitive. The term 'flexible learning' became widely used for a variety of learning approaches. Academics

at my university were encouraged to think about ways in which they could make their teaching and the learning of their students available in more flexible means; to consider how best to deliver their subjects in ways that suit their students and context; to "read and match" (Scott, 1998).

Together with a colleague, I received funding from the university strategic initiatives fund to offer a mathematics education subject in flexible mode in 1997. Part of this entailed encouraging students to learn subject matter content in more autonomous ways, and another aspect of the subject was the use of a computer web-based program to encourage debate about the nature of mathematics and to help students to consider their beliefs about mathematics teaching and learning and to debate the implications of these beliefs. The first part of the subject entailed the writing of workshop materials which were based on our beliefs about the value of learning in and from a community of peers. The workshops were structured so that students could work collaboratively to develop understandings of the three types of content knowledge described by Shulman, as they applied to a component of the elementary school mathematics curriculum. The lecturers were mediators in helping groups develop their understanding of the material.

In the computer-mediated part of the subject we used a web-based conferencing tool called TopClass as the site of the discussion. Two topics were set for the students in the form of quotations. The quotations were:

> *On the nature of mathematics*
> I'd describe mathematics as the calculation of certain things to do with numbers, and the use of certain formulas and methods, simplifying , counting and subtracting and things like that. (Maria, first year prospective primary schoolteacher)
>
> *On the cultural context of mathematics*
> Mathematics is universal, objective and unchanging. It is independent of social, cultural and political values. (Compilation of prospective teachers' comments).

The students were required to respond to these statements in groups of six, using prepared material to help them formulate their responses. Material was available from three sites: web locations given to the students by us, material in the library, and finally responses to the statements written by mathematics educators from a number of countries, whom we had

invited to respond to one or both of the statements. Students formulated a response halfway through the semester, placed it on the Web and then read the other students' responses and posted a second response which took these views into account. (For a more detailed description of this first intervention see Foley and Schuck, 1998; Schuck and Foley, 1998).

The intervention in 1997 was carefully evaluated by us through anonymous surveys, journal entries and open-ended questions on the survey form. The results of this intervention using web-based discussion showed us that students had indeed begun to change their views of mathematics and mathematics education as had been the goal of the intervention. However, a surprising finding for us was that there was a marked increase in negative attitudes towards the computer technology. So while use of the technology had achieved our desired aims of challenging beliefs, it appeared to be accompanied by some undesirable side-effects.

I felt a commitment to removing the impediments to success in using the technology, given that the aims of challenging beliefs appeared to have been achieved with the intervention. Consequently, the following modifications were made to the web-mediated discussion component of the subject:

- a third topic was introduced for discussion as the 1997 students had indicated that they had desired more choice. The statement for this topic was:
  *On the teaching of mathematics*
  The best way to teach mathematics is to give clear explanations followed by drill and practice (George, teacher).
- More mathematics educators were invited to respond, in particular to the new topic.
- Instead of groups formulating one response after a period of approximately 6 weeks and a second response a few weeks later, we implemented a different system so that ongoing support and feedback would be available to students. This change was made in response to the findings that some of the students had found use of the software difficult and unpredictable due to their inexperience or misunderstanding of instructions. The new system had the groups broken into teams of three which posted their responses to the other team on a fortnightly basis. I checked the postings each week and followed up those teams who had not posted a response when required, to ensure they were not experiencing problems. Having to work in a team of three also aided collaboration which had been found to be difficult in groups of six. After six weeks of two teams posting responses regarding the chosen focus statement to each other in alternate weeks,

the two teams were required to combine and write a response out of their collated responses from the previous six weeks.

- A section called Questions and Answers was added to the website, in which I encouraged students to both pose any questions for which they required answers and to answer any questions posed by their peers.

While I found that there was an increase in the valuing of web-based conferencing by students, as compared to the previous year's evaluations, the major area of development for me was in the quality and content of the questions and answers that students posed in the Q&A section. The conferencing tool proved to be an ideal vehicle for encouraging student autonomy, developing logical arguments and engaging in debate within a learning community. Questions were posed, generally by the students, although I posed one which had been raised in a class earlier. Other students would then post their responses onto the web for the whole cohort to see. Initially I experienced moments of great anxiety as incorrect responses were posted and I wondered if I should be intervening to correct those misconceptions. However, after a period of only a few days, invariably other responses would appear, correcting the misconception and providing clearer and more concise explanations. At last, my students were engaged in autonomous learning within their peer community without necessitating my presence as the expert-teller in the learning process. Indeed, I had finally become the mediator in the learning process rather than the director of it.

Further, the issue with which I had been concerned earlier, that of students preferring to engage in enjoyable activities which did not involve deep interaction with the subject matter, seemed to be resolved. In responding to other students' questions, prospective teachers had to engage with the content. Responses had to be more than nurturing self-esteem, they had to justify a mathematical claim or idea. Such responses led to students engaging more deeply with the content and doing so by choice rather than coercion. Students began thinking in mathematical ways as they sought ways of justifying their statements.

**Signposts on the route of self-study**

As a result of my journey of self-study, I offer the following observations:

- Self-study has to be rigorous to be of any significance beyond individual practice. By this, I mean that it has to be thorough, use appropriate research methodology to ensure all voices are heard, and it needs to be well documented.

- Awareness of the literature and context of the self-study is essential for the self-study of teacher education practices to have any far-reaching benefits.
- It appears extremely important for teacher educators to be aware of the beliefs and views of their students about learning and the nature of learning in particular subject areas.
- Emphasising approaches to learning which incorporate attributes of collaboration, support and enthusiasm are not sufficient for good teaching: the importance of content matter knowledge as delineated by Shulman needs to emphasised.
- The use of web-based technologies have much to offer in providing climates for learning which is based on socio-cultural theories.
- It seems critical to be aware of students' evaluations of our teaching and to take these into account in modifying our practice, but this feedback on its own is insufficient in directing reforms, as most people are initially resistant to change.
- Self-study is never complete – changes in context, student body, and cultural practices will all suggest corresponding changes in teacher education practices.

The final point suggests to me that deep and ongoing self-study of teacher education practices is essential if any teacher educator is to be a leader in reform of practices. Furthermore, the study should be rigorous and widely disseminated: it appears that a major obstacle to reform in teacher education occurs if a teacher educator engages in self-study in isolation from his or her colleagues. Those not involved in serious self-study may obstruct the changes suggested to individual teacher educators by their self-studies (Myers, 1995; Russell, 1999). Also, as self-study of practices often leads to discomfort for both teacher educator and students, a climate, in which such challenges to practice are rare and unsupported, will encourage the status quo and inhibit change. Therefore, as participants in the self-study of teacher education practices movement, we are obliged to use our research on self-study to promote its benefits and significance.

On a personal note, my examination of my journey of self-study suggests to me that I should not allow myself to be seduced by the easy route, the route on which students would like to steer me. By persevering with ways of increasing student autonomy and by continuing to assess my practice, not merely from student evaluations, but also from examinations of students' learning and teaching of mathematics, I will gain valuable insights into how to be a more effective teacher educator. This self-study should enhance my opportunities and

abilities to make my students more willing passengers on the road to mathematics education reform.

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