Towards "Breaking the Cycle of Tradition" in Primary Mathematics

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The purpose of this study was to explore the mathematics teaching practices of graduates of a pre-service primary education program designed to develop teachers' capacities to implement non-traditional mathematics curricula. As a complementary component of a large survey study of graduate teachers, eight graduates were interviewed to examine their mathematics teaching practices and influences upon their practices. The teachers were implementing personally developed, constructivist-oriented curricula, while also acting as curriculum leaders. They indicated awareness of how aspects of their pre-service education provided them with the knowledge, skills, and confidence to enact their beliefs about effective mathematics teaching.

A problem facing pre-service mathematics teacher education is the challenge of preparing teachers to "break the cycle of tradition" of mathematics teaching and learning practices that centre on memorisation of facts, and practice of pre-set meaningless procedures, which promote a view of mathematics as lacking creativity, imagination, or critical thought. Research over recent decades indicates that "teachers continue to teach much like their forbears did" (Hiebert, 2003, p. 11), with an emphasis on teaching procedures rather than conceptual understandings. An alternative, non-traditional perspective for mathematics, often referred to as "constructivist", is one in which classrooms are envisioned as places rich in: discourse about important mathematical ideas, the development of mathematical meanings and understandings, and exploration of problems grounded in meaningful contexts (Clements & Battista, 1990; Sparrow & Frid, 2002).

Curriculum renewal and change efforts in mathematics in Australia and elsewhere (e.g., Australian Education Council, 1994; National Council of Teachers of Mathematics (NCTM), 2000) set ambitious goals for schools, teachers, and students by entailing a re-conceptualisation of the nature of mathematics and effective mathematics teaching and learning (Hiebert, 2003; Sparrow & Frid, 2002). To move forward in mathematics education therefore requires substantial learning by teachers and pre-service teachers with regard to their mathematics content knowledge, and their capacities and confidence to plan for and implement "non-traditional" mathematics teaching practices. Thus, there is an ongoing need for research into how to support teachers to develop as professionals who have capacities to break the cycle of tradition.

Background to this Study

The larger research program from which this study arose was designed to tackle the problem of breaking the cycle of tradition in a holistic, ongoing way beginning in pre-service education. Three components of mathematics education – content knowledge, mathematics pedagogical competence, and mathematics professional confidence – formed a foundation for a longitudinal action research cycle of curriculum implementation and evaluation in mathematics pre-service teacher education that was implemented over five

years (and is still in progress). The curriculum initiatives and innovations, along with evaluations of their impact upon pre-service primary and early childhood teachers, are documented in earlier papers (e.g., Frid & Sparrow, 2003, 2004, 2005). However, although there has been evidence of substantial professional learning by the pre-service teachers that indicates they have the content knowledge, pedagogical competence, and professional confidence to begin to break the cycle of tradition upon graduation, the research did not examine the impact of this professional learning subsequent to graduation. In fact, there is little in the research literature regarding the impact of pre-service education subsequent to graduation.

Breaking the cycle of tradition will not occur unless graduate teachers are able to put into practice the non-traditional mathematics curriculum and pedagogical beliefs, ideas, and skills they developed in their pre-service programs. Thus, to begin to address the problem of breaking the cycle of tradition more comprehensively, a graduate survey and small-scale interview study were conducted to examine the questions:

- What are the mathematics teaching practices of graduates from a pre-service program designed to support teachers to break the cycle of tradition in mathematics education?
- What influences these practices?

This paper reports on the findings from the exploratory graduate interview study, while the survey findings are reported elsewhere (Frid, McCrory, Sparrow, & Trinidad, 2007). The significance of this research, as already indicated, is in its potential to inform mathematics educators of mechanisms and outcomes related to the development of beginning teachers as professionals who have the capacities to implement innovative non-traditional mathematics teaching and learning practices.

Theoretical Framework

Within the overall action research program, *teacher professional development* was viewed as a "process of growth in which a teacher gradually acquires confidence, gains new perspectives, increases knowledge, discovers new methods, and takes on new roles" (Jaworski, 1993, pp. 10-11). The curriculum development and implementation of the research program was built upon two main aspects of the literature related to teacher professional development, adult learning theory and professional empowerment, which are summarised below. The framework subsequently developed for the 4-year pre-service primary mathematics education program was named the *Three C's Mathematics Education Framework.* It also is outlined here, to indicate how the 4-year program was designed through analysis and synthesis of the relevant research literature.

Adult Learning Theory

Designing appropriate support for pre-service teachers' learning as mathematics educators requires consideration of how adults learn. Adult learning theory, as proposed by Knowles (1984), emphasises that adults are self-directed learners whose need to learn arises from the interests and challenges of their everyday lives. Further, since adults bring a broad range of experiences, beliefs, values, and ways of functioning to any learning situation, teaching processes that emphasise reflection, self-direction, articulation, scaffolding, and collaboration need to be explicitly recognised and attended to when planning curricula for adults. Learning must be embedded in "contexts that reflect the way

knowledge will be useful in real life" (Collins, 1988, p. 2), and key features of related learning environments must include: coaching and *scaffolding* that provides skills, strategies, and cognitive links; *collaboration* to support personal as well as social construction of knowledge; *reflection* to enable meaningful and purposeful learning; *articulation* to consolidate knowledge and foster communication skills; and *integration* of learning and assessment tasks (Herrington & Oliver, 1995).

Teacher Professional Empowerment

Mechanisms for growth and change must ask teachers to act as their own change agents, while gently challenging ideas and fostering critical reflection upon ideas and experiences. Thus, "coming to know" as a professional is based upon ownership of ideas and related teaching practices, a form of professional empowerment. From an empowerment perspective professional development is an educative process in which teachers make meaningful and thoughtful choices about their practices rather than having change imposed externally (Robinson, 1989). What is key is that teachers act as their own change agents for immediate and long-term goals (Richardson, 1994).

The Three C's Mathematics Education Framework

The literature concerning adult learning theory and teacher empowerment guided development of the *Three C's Mathematics Education Framework* (Table 1).

Table 1
Overview of the Three C's Mathematics Framework

Year	**Mathematics *Content*** (content rich learning activities and exploration of curriculum documents)	**Pedagogical *Competence*** (examination of learning theories, teaching resources, technologies, and the literature)	**Professional *Confidence*** (reflection, articulation of ideas, and authentic application of learning)
1st-Year	• focus on the Space strand; overview of other strands • Maths Basic Skills Test	• social constructivist perspectives on learning and related practical implications for teaching mathematics	• develop and implement single and short sequences of mathematics lessons for children
3rd-Year	• Number & Working Mathematically • number sense and mental computation • numeracy	• examination of children's mathematical thinking and meaning-making	• plan for and assess children's learning (implementation with small numbers of children) • incorporate a wide array of resources and technologies into learning activities
4th-Year	• Measurement, Chance & Data, & Working Mathematically	• further examination of broad range of factors that impact on maths learning, including open-ended tasks, inquiry models of learning, games, textbooks, assessment practices, and catering for diversity	• articulate a philosophy of mathematics teaching • develop a mathematics professional teaching portfolio • participate in authentic professional interviews • prepare/implement program for a 10-week school practicum

Method

Purpose of the Interview Study

One of the purposes of the interview study was to explore beyond the quantitative and descriptive data of the larger graduate survey, through the gathering of more elaborated, explanatory data concerning teaching practices. Since the survey design and descriptive findings are reported elsewhere (Frid, McCrory, Sparrow, Trinidad, & Treagust, 2007), this paper aims to go beyond the description of practices to consider possible reasons for their nature. This focus allows for scope in the consideration of specific examples from teaching or other professional experiences, and possible links between graduate teachers' current practices and previous pre-service learning.

Research Sample

The interview research sample consisted of eight graduates selected from over 20 who volunteered when they returned their written survey in the mail. This sample was purposeful in that it was chosen to include graduates from all four years of the graduate survey (2002-2005) and graduates teaching in a range of locations (Table 2). It is acknowledged that this sample is not fully representative of the population of over 300 graduates from 2002-2005, and that their views and practices cannot be generalised to the larger group. However, since the interview component of the study was intended to identify avenues for further research into links between pre-service education and subsequent teaching practices, the diversity of teaching experiences represented by the graduates was considered sufficient as an initial exploration.

Table 2
Teachers Interviewed, Graduation Year, and School Employment History

Teacher (pseudonyms)	**Graduation year**	**School employment history**
Amanda	2002	Metropolitan school
Elaine	2002	Rural and remote schools
Lisa	2003	Metropolitan school
Nicola	2003	Rural school
Nancy	2003	Remote school
Alice	2004	Rural school, then metropolitan school
Yvonne	2004	Rural school
Wendy	2005	Metropolitan school

Data Collection and Analysis

Interviews were semi-structured in nature, with interviewees' initial responses examined further through requests for explanations and specific examples. The interview questions focused on the teachers' experiences related to: how prepared they were in mathematics education for the reality of their first job; factors that helped or limited their mathematics teaching; how they have used their mathematics teaching portfolio; and in what ways they were making an impact on mathematics learning in their classroom or school. These four foci were intentionally broad and contextual in nature, rather than asking an interviewee specifically to outline her teaching practices and related influences. In this way the interview data complemented in a holistic way the survey data that had been

obtained from specific, directed questions. The contextual nature of each of the four foci provided opportunity for data to be obtained concurrently for both research questions (practices and influences).

The interviews were conducted in the July 2006 school term break, by telephone or at the university campus. They were conducted by an independent research assistant who was a qualified teacher, did not know the teachers, and had not been involved in their pre-service education program. Interviews lasted 30-45 minutes; they were audio recorded and later transcribed. Data analysis initially involved summarising across all eight teachers the responses for each of the four foci, and then proceeded inductively through a grounded approach (Powney & Watts, 1987). Initial emergence of key themes related to practices and influences upon practices were derived from the summaries and then examined further via re-visiting the transcripts for supporting as well as contrary evidence from the specific examples given by the teachers.

Findings

This section is structured around the two research foci (practices and influences), with the emergent themes each summarised briefly and explicated with examples from the interview data.

Classroom Teaching and Related Professional Practices

Three key aspects of classroom teaching practices emerged: (i) non-traditional teaching; (ii) "fun" mathematics; and (iii) classroom-specific curriculum development. An additional factor emerged as a key aspect of the teachers' broader professional practices related to mathematics: (iv) acting as a curriculum leader.

Non-traditional teaching. All the teachers spoke of teaching in what could be considered a constructivist perspective because it involved students in developing meanings and understandings through active engagement in learning activities (Clements & Battista, 1990). In this regard they also frequently mentioned using "hands-on" materials as a regular and essential feature of supporting students' mathematical thinking and meaning-making. For example, Elaine stated:

> … engaging the children in maths and really getting them to do stuff and working it out in their brains. … Getting the basic concepts across to them [indigenous students at a small school] was a challenge. So to have hands-on, talking about fractions and things, I'd get a cake and we'd cut it in half, … and give them the knife and cut it into quarters, and we'd sort of work our way down and they really got to visualise what it was to have a whole and then a half and then a quarter, and that sort of thing because fractions is a really tricky thing to get across to kids who really don't know much about numbers. (Elaine)

Other aspects of constructivist-oriented rather than more traditional teaching were evident in the teachers' references to how they used open-ended tasks, calculators, or other technology, while also avoiding prescribed textbook or worksheet exercises.

> I do try to think of more open ended activities because I've got such a range of kids. So then I can help the ones that are having problems and give more, and give extra to the ones who can do it all with their hands tied behind their backs. (Wendy)

> I did calculators [in my portfolio] and I try to use those with the kids. … We do lots of fun things and all those sorts of calculator games and stuff like that. (Lisa)

> And so I was really determined to use the influence Len Sparrow had on me. … I didn't use the books in the classroom because they're all those old textbook, workbook things. (Nicola)

"Fun" mathematics. Most of the teachers mentioned attempting to make mathematics experiences "fun", so that students would develop positive attitudes towards mathematics and be motivated to do mathematics. What they meant by "fun" was in fact more than enjoyment. It was learning oriented, involving motivation and enthusiasm, challenge and persistence, success, and a sense that mathematics can be relevant and useful.

> Well I know I'm making a difference because they are meeting the criteria of the outcomes. But the thing, the biggest thing I think is that they actually are enjoying it and are asking to do more. They like the challenge of mental maths and things like that, and "Can we do more?" and "When are we going to do that?" It's the enthusiasm for learning that's been the main thing, and the fact they enjoy maths is great. (Nancy)

> … a lot of the time the kids can be, "Oh, I can't do maths. I just can't do it". And therefore they don't try. But if you do it in an interesting context and in a way that encourages them to think about what they're doing it makes them realise that they can do it and it's not such a big scary thing at all. From the children I have taught I can see their change in attitude. … they can get through it if they are empowered to get through it. (Elaine)

Classroom-specific curriculum development. The teachers spoke of developing their mathematics curriculum locally and flexibly, in the context of their classroom and their students' learning needs. Some had taught in schools in which "you had to follow the textbook", yet even then they made efforts to "be creative" by incorporating hands-on activities and having students use their "brains a bit" (Elaine). In this regard they expressed strong beliefs that a mathematics curriculum cannot be based largely on prescribed textbook or worksheet activities if it is to support effective mathematics learning for the diversity of students in a classroom. Inherent in these beliefs are non-traditional views of mathematics learning and teaching; specifically, the same exercises at the same time are not appropriate for catering for students' developmental and achievement levels. Thus, many of the teachers indicated they preferred to use their professional knowledge and knowledge of their students to make mathematics curriculum decisions.

> We did try to program together for the first term and it just didn't work. It felt like I was banging my head against a brick wall, because her kids do worksheets, lots and lots of worksheets, and they're just five [years old]. (Wendy)

> You can pick and choose the parts that suit you and the different … like using the hands-on stuff, like using calculators. … We make our own lessons up because we said you can't have a textbook in Years 1 and 2. It's a guideline. … there's still room for extending the kids ... if they can do what's in the book you can still go over and above it if you feel they need to, or go back and re-teach a few things if they've missed something. (Lisa)

Acting as a mathematics curriculum leader. There was evidence that some of the teachers, even though they were "novice" teachers, were taking on mathematics leadership roles in their schools. In some cases these roles arose from personal initiatives to do new things in a school related to enhancing mathematics learning, indicating a degree of confidence and professional knowledge on the part of the teachers. Other forms of leadership involved encouraging and supporting other teachers to try new things, by sharing ideas, expertise, or resources. Yet another form of leadership that was mentioned by one teacher was that of acting as a role model, simply by doing different things that later proved to be effective in supporting students' mathematics learning.

> They gave me the opportunity to do the role [maths specialist], which I thought was quite strange because I was very frightened of maths. I thought, "Why me?" … So I go in and I actually give teachers ideas on how they can use the technology with their maths. We've got all these interactive whiteboards, so I train teachers on using the interactive whiteboards in their maths. (Amanda)

> Every time I come back from a conference I report at the following teachers' meeting on what I've learned and show them some stuff. … Last year one of the teachers was particularly receptive to the calculator program I brought back for him … so I had a win there. (Nancy)

> I started, in the newsletter I have a maths corner where I put a maths strategy in for the parents to help their kids. And a maths competition. (Nicola)

> That's actually been really amazing, the difference. ... They have done so much better … from someone who doesn't use the [text]books. … The other year 6/7 teachers, when it's maths they opened up to a certain page in the book and they all did that in the book. Now I never did that, and I was worried about whether they [the students] would be okay with everything. But from the results from different maths tests that they have to do for year 8, it's really shown me I've improved their maths. … I've had some teachers who have said to me, "I've never thought of doing it that way". (Nicola)

Influences on Practices

Two factors emerged as key influences upon mathematics teaching practices: (i) university learning; and (ii) school support or restrictions.

University learning. Since mathematics teaching portfolios (university learning), were specifically asked about in the interviews, their prominence was at least partially a product of the data collection instrument. However, of relevance here is what other aspects of university learning emerged as relevant, and which aspects of mathematics portfolios had an ongoing influence.

With regard to portfolios, specific teaching ideas such as the use of calculators, other technology, games, or mental computation were cited as useful in subsequent teaching. To a lesser extent there was mention of underlying principles for teaching particular mathematics concepts. What received the most mention, however, was the mathematics teaching philosophy developed in the portfolio.

> I've definitely used my maths portfolio, because I looked at maths through technology. So the whole thing was based on how technology can be integrated into our maths. (Amanda)

> I have used my general mathematics philosophy which sort of guides my maths teaching in that I still have the same values I did when I did the portfolio, and I still want to achieve the same things with my children. (Alice)

> The main thing is my philosophy, my beliefs. … I don't think I'll ever stop believing kids need to have fun in their maths, and they need to think and do and play around with stuff, and talk about it. Those are my core beliefs and I don't think they'll change. They might adapt slightly. (Lisa)

Beyond the learning attained at university from development of a mathematics teaching portfolio, what emerged as highly influential were the mathematics education lecturers and how they served as role models.

> My first year out I had year 6/7's and I was determined that if I didn't use the stuff I'd learnt from uni in my first year I never would. And so I was really determined to use the influence Len Sparrow had on me. (Nicola)

> I still think back and think, "What did I do in maths class? How can I teach this concept to my kids?" And I was chatting to some other Curtin graduates at the Beginning Teachers' Seminar and they were saying that they too have Len and Sandra moments. "Oh, what did Len do, what did Sandra do for that to help?" (Wendy)

School support or restrictions. A key feature of this theme was that personal beliefs and values related to mathematics teaching and learning, along with their resonance or incongruence with the beliefs of others at a school, could lead to dissatisfaction with teaching.

> The standard at that school was that you had a textbook and you had to follow the textbook, so I really didn't have a whole lot of room to be creative with those kids. ... I felt restricted because at uni everything was so exciting and energetic and so hands-on. (Elaine)

However, at the same time, some of the teachers noted specifically how their convictions to follow their beliefs, regardless of restrictions or the practices of other teachers in the school, were a guiding source for daring to be different and enacting non-traditional teaching practices.

> Things that have limited it? Simply old ways of thinking. You know you get really good teachers you can collaborate with, that have other experience, but you get other teachers that say, "No calculators in this classroom", or … "My kids aren't using counters for things like that". It's my classroom and if I want them to use counters, well they're going to use counters basically. And that's what my maths beliefs are and it's going to work. And you know what? Sometimes you have to say, "Stuff it". ... You just have to take a bit of a risk sometimes. (Lisa)

Conclusions and Implications

The findings from this study indicate that it is possible to "break the cycle of tradition" in primary mathematics education. More specifically, it is possible to prepare pre-service primary teachers who, subsequent to graduation, have the content knowledge, pedagogical competence, and professional confidence to put into practice non-traditional mathematics curricula. They can develop classroom-specific mathematics curricula that cater for diverse learning needs, use constructivist-oriented teaching strategies, and foster a view of mathematics as a challenging, relevant, enjoyable, and achievable endeavour. Further, they can act as change agents through a variety of forms of curriculum leadership, including serving as a specialist or coordinator, being a role model, fostering collaboration and sharing of ideas, or initiating new ideas and activities at a school.

However, the small scale nature of this study necessitates that these conclusions be made with some qualifications, because the findings cannot be generalised to all graduates. They cannot in fact be claimed for all eight of the teacher interviewees. For seven of the eight teachers the evidence was convincing with regard to the conclusions. The eighth teacher, Yvonne (2004 graduate), was somewhat different from the others in that she spoke of struggling with her mathematics teaching and not knowing what to do with the diversity of achievement levels in her classroom, and she could say very little about what she had learned in her pre-service program or her mathematics teaching portfolio.

The findings do, nonetheless, show what is possible and what is promising. It is in this context that the following discussion of practical implications examines aspects of the teachers' pre-service experiences and current practices that appear to be prominent in their capacities to begin to break the cycle of tradition: (i) development of a mathematics teaching philosophy; (ii) breadth and depth in mathematics pedagogical knowledge; and (iii) professional confidence.

Development of a Mathematics Teaching Philosophy

The fact that most of the teachers, even up to 4 years later, could outline how their mathematics teaching philosophy impacted upon their practices implies the development of a philosophy as a requirement of their pre-service program supported their later teaching endeavours. They spoke of their beliefs and values, but more importantly, of how these guided their practices. This latter point must be noted explicitly in that the development of a mathematics teaching philosophy entails more than outlining beliefs about mathematics teaching. It necessitates translating beliefs into practice, that is, articulating how classroom environments, learning and assessment activities, and teaching strategies can be constructed to attain the goals of one's beliefs. A philosophy is more complex than an outline of beliefs, and thus, this research goes beyond prior research related to the nature and role of beliefs in mathematics teaching. Much previous research has neglected the practical components of an examination of beliefs, by not addressing how to put beliefs into practice in practical ways in the context of actual classroom teaching. A mathematics teaching philosophy and related teaching portfolio require this articulation and application, and hence a practical implication of this research study is that the development of a mathematics philosophy and portfolio can support beginning to break the cycle of tradition.

Breadth and Depth in Pedagogical Knowledge

The teachers showed breadth in their pedagogical knowledge in that they displayed awareness of a wide range of mathematics resources, teaching strategies, and learning activities that can motivate and support meaningful mathematics learning. They showed depth in their pedagogical knowledge in that they could articulate *why* they used particular methods in relation to *how* they facilitate mathematics learning. That is, the teachers displayed understandings of the research on how children learn mathematics, and importantly, how to apply those learning theories to the development of mathematics curricula. The implications here are that teachers who have understandings of mathematics pedagogy, *along with* capacities to translate those understandings into classroom learning experiences, will begin to be able to break the cycle of tradition. What is not as clear here, in comparison the role of the teachers' philosophies, is the degree to which the teachers' pre-service program had direct impact upon their later breadth and depth in pedagogical knowledge. It is however reasonable to note that a key aspect of the pre-service teachers' development of a mathematics teaching portfolio was that they had to justify the content their portfolios. Specifically, they had to use a framework of "what-why-how" (Frid & Sparrow, 2003, 2004) to prepare portfolio items, and then to justify them within authentic interviews with school principals and other educators.

Professional Confidence

Several of the teachers were acting in leadership roles, and some clearly were "daring to be different", even in the face of restrictions and adversity. It takes professional confidence to take the risks needed to enact teaching practices that differ to those of colleagues in a school. The fact that these actions were being taken by "novice" teachers needs further examination. In this study there was evidence that the teachers' professional confidence arose from awareness of their beliefs, values, and philosophy, along with convictions to act in congruence with them. The additional factor in evidence was that they had well-developed pedagogical knowledge of how to translate their beliefs and philosophy

into practice. Their professional confidence was not independent of their teaching philosophy and pedagogical competence; they were not separate. Thus, a practical implication here is that pedagogical competence along with related professional confidence can lead to teachers to begin to break the cycle of tradition.

In conclusion, a final statement of what is promising in addressing the problem of breaking the cycle of tradition is that this study implies: it is possible to prepare pre-service teachers to be thinking-acting-leading mathematics teachers – teachers who think critically about their professional practices while also serving as educational leaders who take action and implement changes to enhance mathematics teaching and learning.

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