

# Using Mathematics Teaching Portfolios to Empower Pre-Service Primary Teachers

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This research examines the learning of 4<sup>th</sup>-year pre-service primary teachers (N=62) engaged in development of a mathematics teaching portfolio. An interpretive research approach was used to analyse data from classroom observations, draft and final portfolio work samples, student reflection sheets, and external assessor interview reports. The findings indicated the pre-service teachers developed substantially in their confidence and reflective capacities as mathematics teachers as well as their capacities to clearly articulate and justify ideas for innovative mathematics teaching and learning practices.

One of the challenges facing pre-service teacher education is the need to respond to the tension between the development of individuals as professionals and the demands of society and educational authorities for ‘technical competency’ (Frid & Reid, 2002). This is the case within all fields of education, but within the field of mathematics education it has particular relevance because current reform efforts in mathematics education have been setting ambitious goals for teachers (e.g. Australian Education Council, 1994; National Council of Teachers of Mathematics, 2000). Reform efforts present a view of mathematics classrooms as places for “engagement in rich discourse about important mathematical ideas while exploring problems grounded in meaningful contexts” (Sparrow & Frid, 2002, p. 71). To move forward with reform efforts in mathematics education therefore requires substantial learning by teachers with regard to their knowledge, confidence, and capacities to plan for and implement ‘non-traditional’ mathematics teaching practices.

A vehicle that has attracted recent attention in educational research on teacher development and change is that of professional portfolios (Frid & Reid, 2002; Lyons, 1998; McLaughlin & Vogt, 1996). It is claimed that portfolios demonstrate ‘professionalism’ because the process of portfolio development necessitates articulation and development of knowledge, skills and values deemed essential for classroom teachers, along with capacities for and a commitment to lifelong learning, innovation and the ongoing improvement of education. It was this potential to engender and support teacher development in a systematic, holistic way that prompted this study into the use of portfolios to empower pre-service mathematics teachers to enact change and innovation in mathematics teaching and learning practices. Specifically, the study aimed to examine this question:

- What mathematics teaching professional capacities are pre-service primary teachers able to provide evidence for through development of a mathematics teaching portfolio?

The significance of this study, as already indicated, lies in its potential to inform mathematics educators of mechanisms and outcomes related to the development of pre-service teachers as mathematics teaching professionals. Further, portfolio development requires both breadth (for demonstration of knowledge and skills) and depth (with regard to individuals’ learning to think critically and then justify and apply ideas). At a more

theoretical level, this research can offer insights into frameworks or models of teacher growth.

## Theoretical Framework

### *Adult Learning Theory and Situated Cognition*

Designing appropriate support for pre-service teachers' learning as mathematics educators requires consideration of how adults learn. Adult learning theory – the science of andragogy – as proposed by Knowles (1984) emphasises that adults are self-directed learners whose need to learn arises from the challenges they encounter in their lives. Adults bring a broad range of experiences to learning situations, along with personally unique beliefs, values, and ways of functioning. Appropriate professional learning opportunities for teachers must therefore recognise that teachers need opportunity to engage in reflection and action that is self-directed and related to the challenges they encounter as teachers. More specifically, these learning opportunities need to involve the teachers in self-diagnosis of learning needs, formulation of their own learning objectives, mutual designing and carrying out of learning plans, and self-evaluation of learning (Knowles, 1984).

In congruence with some of the fundamental ideas of adult learning theory are the principles of situated cognition or situated learning, particularly concerning the need to embed learning in “contexts that reflect the way knowledge will be useful in real life” (Collins, 1988, p. 2). Herrington and Oliver (1995) identified key features of learning environments that could be viewed as supportive of situated learning. These included:

- Collaboration to support the cooperative construction of knowledge;
- Coaching and scaffolding that provides skills, strategies and links that students are initially unable to provide;
- Reflection to enable abstractions to be formed;
- Articulation to enable tacit knowledge to be made explicit; and
- Integrated assessment of learning within tasks.

The notions of collaboration, self-direction, scaffolding, reflection and articulation that are highlighted by both adult learning and situated learning theories were used in this research to inform the design of the teaching unit within which the study was conducted. An outline of the key features of the related teaching and assessment activities for portfolio development is given in the upcoming Method section.

### *Teacher Empowerment*

Robinson (1989) discussed an empowerment paradigm for teacher professional development, emphasising that professional development from this perspective should be an educative process in which teachers make meaningful and thoughtful choices about their practices rather than having change imposed externally. An empowerment perspective explicitly stresses that teachers should have ownership of their professional learning so that ‘coming to know’ as a professional is based on their own reasoning processes in relation to their experiences, and so that their own ideas and voices are effectively integrated with those of others (Cooney, 1996). What is key here is that the teachers themselves mediate the ideas, construct meanings from them, and act according to their own

values and decisions (Richardson, 1994). This empowers them to act as their own change agents for immediate and long-term goals. In working with pre-service teachers, as in this study, an implication of these points is that learning activities need to create situations where teachers consider their beliefs and practices, particularly regarding what they value and do, why they do it, and how they do it. For this study, this last key facet of empowerment – fostering reflection on beliefs and practices – was an essential component of the design of the teaching unit, as outlined in the next section, particularly since reflection is an integral component of portfolio development. It is emphasised also within adult and situated learning theories, but is further articulated from the context of empowerment so as to stress that:

Only by confronting what you believe and reflecting on what you believe will you become a teacher who can match what you philosophically believe with what you practise in the classroom. Teachers who can do this appear to be the most empowered. (Harris, Turnbull, Fitzsimmons & McKenzie, 2001, pp. 1-2).

## Method

Since its aim was to understand the nature of a professional development learning endeavour, this study was designed as a naturalistic, interpretive inquiry. Hence, qualitative methods, with their capacity to emphasise contexts, meanings, and individuals' interpretations, were adopted. More specifically, the research involved four classes (N=62) in 2002 of 4<sup>th</sup>-year Bachelor of Education (BEd) pre-service primary teachers, with the researchers as the class lecturers in the role of 'participant-observers'. The sample consisted of 2 males and 60 females, which is typical of the enrolment patterns in the BEd program.

### *Research Context*

The unit in which the students (the pre-service teachers) were enrolled, Mathematics Education II, is a compulsory unit for the first semester of the students' final year. Students had previously completed 1\_ other units with a focus on mathematics education. The students had no prior experience with professional portfolios, and hence, the unit was designed to introduce and support portfolio development in ways that had proven successful in previous research by one of the researchers (Frid & Reid, 2002; Reid & Frid, 2000). Although this previous work had indicated portfolios can support pre-service teachers in their learning, it must be noted that the research had been conducted as a longitudinal study over 3\_ years with a small group of volunteers. It was important in the study reported here to determine if the potential of portfolios could be realised within mainstream teaching, and in particular, within the 'challenging' curriculum area of mathematics.

To fit within the adult and situated learning theories of the theoretical framework of the research, it was decided to stipulate key components for the mathematics teaching portfolio while simultaneously allowing for individual choice. The unit outline therefore stipulated that a student's mathematics teaching portfolio must, at minimum, include: a personal philosophy of mathematics teaching, an item related to assessment in

mathematics, an item related to the use of technology in mathematics teaching and learning, a 3-week mathematics program, and an item on a topic of one's choice.

As a mechanism to support portfolio development as an 'authentic' professional task reflective of the realities of a professional teacher, and hence to fit within adult and situated learning theories, it was decided to include, as formal components of assessment for the unit, a public portfolio exhibition and interviews with school principals and other educators. Students therefore engaged in the formulation, planning, researching, implementing, and reporting on their personal learning agendas within the context of knowing they would need to present and discuss their mathematics education ideas with experienced educators.

### *Data Collection and Analysis*

Data were collected from: classroom observations; draft and final portfolio work samples and the written feedback provided to students on draft and final portfolio items; formal reflection sheets completed by students at the beginning, middle and end of the semester; and external assessor reports completed at the end of the semester at a final Portfolio Exhibition that included students participating in formal interviews with school principals and other local educators. The multiple data sources, by including data sourced from lecturers, students, and external educators, served as a form of triangulation for the research.

Data analysis proceeded inductively through a grounded approach (Powney, & Watts, 1987), with the initial emergence of key themes within the classroom observations, student reflections, and draft portfolio work samples considered further within examination of data from the final portfolios, student reflection sheets, and external interviewer reports.

## Findings

Four key aspects of the students' professional development as mathematics teachers emerged over the semester related to their increased capacities: (i) to articulate and justify ideas for 'modern' mathematics education practices, (ii) to make connections between ideas, and between theory and practice, (iii) to value and effectively use reflection as a professional learning tool, and (iv) to feel confident and knowledgeable as mathematics teachers who have relevant and valuable ideas to share with other professionals. These four key themes were not distinct, but rather were interlinked so that, for example, reflection was not independent of increased capacities for making connections, or confidence was not independent of increased skills at articulation and justification of ideas.

### *Articulation of Modern Mathematics Education Practices*

Weekly class activities required students to prepare and share draft portfolio items, as a process intended to scaffold development of capacities to identify, summarise, analyse, and communicate key ideas from readings and research on a topic. Early in the semester, first drafts tended to be in the form of a mini-essay or a bullet-point list. Consequently, much written feedback on drafts related to a need to "present ideas concisely yet comprehensively", as well as to demonstrate that one has "digested and thought through thoroughly the ideas", rather than "borrowing" them from readings. Further, the lecturers

developed a *what, why, how, who else says so-framework* as a tool to emphasise that in presenting an idea about mathematics education practices, particularly concerning innovation, one needs to communicate *what* the idea is, *why* it is valuable to mathematics learning, *how* a teacher could put it into practice, and what the research and professional literature reports about the idea (*who else says so*).

The framework appeared to serve students well for analysing and synthesising ideas, and then structuring their portfolio items. As the semester progressed, students' draft portfolio submissions improved with regard to the clarity and justification of ideas, to the extent that in the final portfolio submission most students earned 7-9 out of 10 as a grade for many of their individual portfolio items. What they did not achieve as fully was a capacity to communicate a sense of ownership of ideas. They provided evidence of much increased knowledge about and reasons for modern mathematics education practices, but the degree to which this knowledge was strongly embedded in their beliefs and commitments was not as easily identifiable. For example, in the following excerpts from reflection comments on what they had been learning, Tracy comments on specific knowledge and skills, whereas Daisy focuses on the ownership and personal construction processes of her increasing knowledge:

I feel I am confident in – applying the Curriculum Framework and Student Outcome Statements through programming, stating clear objectives, being able to use a variety of assessment techniques, applying the technology process through mathematics and implementing manipulatives through a variety of learning experiences. I feel that I am still developing in the area of long-term planning and finding rich and varying learning experiences in mathematics for the children. (Tracy)

I found I really needed to go back to my beliefs about teaching to develop my portfolio. There were so many concepts of teaching that attract my attention, however I realised it isn't possible to take on all these ideas. Therefore, my final portfolio contains ideas that I am really passionate about, comfortable in using in my teaching and that are right for me. I also realised that I really do believe in the concepts outlined in my philosophy because they are so strongly evident in my program. I have come to understand that my portfolio will be a changing document as new research and new teaching styles are developed and I become more experienced as a teacher, but teaching styles and preferences should always lead back to my philosophy. (Daisy)

Both these excerpts also show how the students were involved in reflection on their learning, a focus of one of the upcoming sections.

### *Making Connections*

As students showed development of their skills to articulate and justify ideas they also showed they were making connections between key ideas, with previous learning in their BEd program, and between theory and practice. To a certain extent this was a product of the *what, why, how, who else says so-framework*, particularly the *who else says so* component. However, it also appeared to be linked to the fact students had choices in what they focused upon within each portfolio item. They could explore things that had caught their attention and they had learned a bit about in other units, mathematics education or otherwise, for example, multiple intelligences, play and games, or manipulatives. They could also re-visit teaching ideas they been exposed to during school practicums, for example, the use of think boards in mathematics lessons, or the use of particular assessment techniques. Finally, it must be noted that it was stressed to students in class discussions and in written feedback on draft portfolio items that they should strive to make

sure their mathematics teaching philosophies were not “just stuff” or “empty words”, but rather, were in evidence in later parts of the portfolio.

An overall sense of cohesion or connectedness was included as a component of assessment of the final portfolio submission. This was where the portfolios differed most from one another, in spite of most students showing they were making connections in their professional learning. The portfolios that best established connections from one part to another were those in which a student had attempted to establish links between her mathematics teaching philosophy and later portfolio items. This was often through the use of a metaphor to communicate key ideas of the philosophy, or the use of a theme around which to base the portfolio. Example metaphors included making comparisons between mathematics teaching and learning and house building, team sports, music, an artist’s palette, cooking, or the seaside. Themes included the use of children’s literature to support mathematics learning, the integration of music and mathematics, or the integration of technology into mathematics learning.

What also distinguished the ‘connectedness’ of a portfolio was the degree to which an underlying consistency in learning theory was documented. That is, although students were guided by the *what, why, how, who else says so-framework* to make relevant connections to professional literature, these connections did not necessarily guide students to deeply analyse ideas to the extent that they formulated their own personal theories of mathematics learning from a synthesis of other theories. The following final reflection sheet excerpt is from a student who successfully built her portfolio by thoughtfully integrating aspects of learning theories as foundations to support her ideas:

In making and combining this portfolio I have been able to bring together and summarise three major educational theories i.e. the theory of Multiple Intelligences, the Project Approach and the Reggio Emilia approach to learning. In doing so, I have strengthened my skills in critical analysis. I have also learned how to apply the key ideas behind these theories when planning a maths program for early childhood. Doing this was a learning journey in itself, having to read-think-write-reflect-adapt constantly. (Shannon)

### *Reflection*

Students had been required for the previous 3\_ years of their BEd program to ‘use reflection’ as a learning tool, having had assessment tasks related to reflection via such things as journals, micro-teaching, lesson evaluations, case studies, and critiques of readings. This was, however, the first time they had been in a position where reflection was used in an ongoing, integrated way to actively revise and refine ideas, beliefs and knowledge. That students did engage in this process deeply was in much evidence, in their weekly class discussions, and in their reflection sheet comments:

When creating a portfolio it is important that what goes into the portfolio is frequently looked at and revised. ... During the semester I continually learnt new things regarding mathematics teaching and learning and this new knowledge had a direct impact on my portfolio items in that I had to make amendments to them in order to either incorporate this new information or improve existing information. (Elena)

I seemed to be ever changing parts of my portfolio in order to make it better. However it is still not complete. There are so many areas that need to be investigated and extended. Once I begin teaching, my beliefs might also change and develop. In completing this portfolio I learnt so much more

about mathematics teaching. It really does not need to be the stereotyped ‘boring’ subject that is often portrayed as. (Isabel)

What was particularly noteworthy about the students’ comments about reflection was not just how much they had used reflection, but rather, that the comments highlighted how students had learned to value reflection as an essential component of their professional learning:

I learned that when you reflect on something there is always something you didn’t see or missed the last time!! It’s a crucial aspect of furthering your knowledge and forces you to look at things more closely. It’s a form of assessment, which allows us to modify our teaching experiences. (Carla)

### *Confidence*

Confidence as a theme related to research question 1 did not emerge as prominent until late in the semester, as class discussions began to consider the nature and happenings of the final Portfolio Exhibition and interviews. Students felt very nervous and somewhat overwhelmed at the prospect of being interviewed by influential educators they had never met. The students had had much practice during the semester in sharing and explaining and their ideas with people they knew, each other and the lecturers, but they had not had to clearly articulate and justify their ideas to educational experts from other contexts. It was a daunting task for most of the students, but the reality of the interview as an authentic professional practice was in itself a catalyst for development of their confidence as mathematics educators. They assisted each other, via mock interviews and peer assessment of their portfolios, to prepare for the interviews. Their comments after the interviews highlighted the impact the process had on their confidence in their knowledge as mathematics teachers:

I felt ... proud of what I have achieved. I feel that I have been able to justify what I have compiled in my portfolio and I have articulated the knowledge well. (Tracy)

It was brilliant. This helped in giving me confidence and helped me realise that I really know my stuff. (Helen)

The end result was “brilliant” for the lecturers also, who received only positive feedback from the external assessors and other visitors to the Portfolio Exhibition. Thus, the interviews emerged as a vital aspect of the processes that supported students’ portfolio development.

## Conclusions and Implications

In summary, it is noted that students’ professional learning as mathematics teachers showed increased capacities to: (i) articulate and justify ideas for ‘modern’ mathematics education practices, (ii) make connections between ideas, and between theory and practice, (iii) value and effectively use reflection as a professional learning tool, and (iv) feel confident and knowledgeable as mathematics teachers who have relevant and valuable ideas to share with other professionals.

As a technology – a tool for addressing the problem of a lack of mathematics confidence and pedagogic knowledge – the use of portfolios showed much promise, particularly for empowering pre-service teachers to serve as change agents in reform efforts

in mathematics education. This claim is in evidence in the following excerpts from students' reflection sheets and related advice to future students:

It helped me realise that I knew all my work and all I had to do was explain it in layman's terms. And I did! Cool! ... That I am a professional (soon to be) teacher. That I will be imparting my innovative ideas about teaching, assessment and the curriculum framework and student outcome statements to future teacher colleagues. ... Don't perceive yourself as a student in the interview. You are a beginning teacher and you know what you are going to do in maths and it's all there in your portfolio. (Natasha)

I have become aware of many of my hidden strengths and have found that even my fear of maths, which I thought was a weakness, is actually one of my biggest strengths, as it helps me to plan, program and explore maths with a real purpose, knowing I will offer my children more than I was given. (Carla)

What this research has raised as issues for mathematics teacher education and related research, in relation to the development of teaching portfolios, are the following questions:

- How can the portfolio process be further developed to support pre-service teachers in their development of connections in and ownership of their professional knowledge?
- What is the potential of a mathematics teaching portfolio developed across a longer time period within students' pre-service education?
- To what degree does the professional empowerment of pre-service teachers as identified in this study extend to empowerment to enact mathematics education reform after graduation?

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