Preparing preservice teachers to step up to the intention of the new Australian mathematics curriculum: Can a productive disposition be reignited?

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The *Australian Curriculum: Mathematics* (ACARA, 2010) emphasises that mathematics learning must go beyond the development of mathematical knowledge to include four 'proficiency' strands of: understanding, fluency, reasoning and problem solving. These proficiency strands have been built into the curriculum in an attempt to ensure "proficiency in mathematics skills is developed and becomes increasingly sophisticated over the years of schooling" (p. 2). Hence, the teacher educator's role is to ensure preservice teachers become proficient mathematicians who can effectively communicate the 'how and why' of mathematical ideas in ways that make it easy for others to understand. However, research reveals that teachers are often unsure what thinking, reasoning and working mathematically looks like in practice. Aware of this gap in knowledge, abilities and language needed for mathematical proficiency, the first year subject, *Numeracy in Education* (Klein, 2009), was designed to help preservice teachers experience firsthand a pedagogical structure that would facilitate effective representation, justification and communication of mathematical ideas.

This research investigated and analysed through a qualitative content data analysis preservice teachers' reflective discussion board comments to determine the success of the subject in preparing them to step up to the demands of the new curriculum. The findings revealed that inquiry-based learning, when structured, supported personal sense-making in ways that some preservice teachers constructed new and meaningful knowledge about the 'how and why' of mathematics, or in some cases they reported that their existing understandings became more sophisticated. The comments revealed that structured inquiry and personal sense-making appeared to increase preservice teachers' feelings of competence and confidence to teach mathematics effectively. The data can inform teacher educators and researchers, policy makers and teachers in planning for the future.

Introduction

The premise of this paper is that the development of a 'productive disposition,' implying a "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy" (Kilpatrick, Swafford & Findell, 2006, p. 5), is an integral factor required to teach and learn mathematics for proficiency. Mathematical proficiency, according to the recent *Australian Curriculum: Mathematics* (Australian Curriculum, Assessment and Reporting Authority, 2010), involves confident development of mathematical understanding and procedural skills, problem solving and reasoning abilities. As we taught in and researched the numeracy subject, we wondered if continued learning depended on the simultaneous development of all three interrelated components; robust knowledge, thinking processes and productive dispositions.

The problem is that over the last twenty years the quality of Australian students' mathematical knowledge and abilities has "deteriorated to a dangerous level," according to a report to the Group of Eight Universities (Brown, 2009, p. 3). Masters (2009) also reports on the apparent decline in Australian students' numeracy skills suggesting that the way forward is to improve the quality of classroom teaching. However, in her extensive work with teachers and preservice teachers Rammage (cited in Brown, 2009) found mathematical phobic dispositions common. Anxiety can be debilitating for preservice teachers who are expected to draw on and extend their existing mathematical understandings to develop the proficiency needed for achieving that same goal with their future students. The aim of the first year subject, *Numeracy in Education* ED1491 (Klein, 2009), was to facilitate preservice teachers' development of robust mathematical knowledge, dynamic thinking processes and productive dispositions. The objective of this research was to collect data from reflective anecdotes on an online discussion board to investigate preservice teachers' views about whether a negative disposition towards mathematics can be transformed, and if so, how?

Becoming mathematically proficient

A deep understanding of what mathematical proficiency involves is necessary to support successful implementation of curriculum intentions. The proficiency strands have been adapted from Kilpatrick and colleagues' 2001 version of *Adding it Up* (National Curriculum Board, 2009). Recognising the complexity of mathematics teaching and learning, Kilpatrick and colleagues (2006) suggested that no single term captures all of the features of what successful mathematics learning involves. However, as they see it, the development of 'mathematical proficiency' is the most applicable term, and involves five interdependent strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. The Australian curriculum (ACARA, 2010) uses three content strands and four proficiency strands, understanding, fluency, problem solving and reasoning, to describe 'how' the content is to be explored through thinking, doing and communicating mathematically.

Teaching mathematics is unique according to Ball, Hill and Bass (2005) because it involves knowing the mathematics, as well as knowing how a classroom of individual students might be thinking about or getting confused by those ideas. Thus, the teacher educator's role is to ensure preservice teachers, including those with mathematical anxiety, are themselves proficient and 1) can effectively communicate the 'how and why' of mathematical ideas and how they are related, 2) understand the thinking processes involved in developing those ideas, and 3) facilitate students' development of productive mathematical dispositions. These three interrelated aspects frame this paper.

Developing robust understandings

Over twenty years ago Skemp (1986) believed that understanding a mathematical idea involved being able to explain how and why it is true. Yet, often teachers of mathematics in Australia focus on asking students to follow repetitive procedures without reasons rather than encouraging them to explain their thinking (Hollingsworth, Lokan & McCrae, 2003). The consequence can be the development of superficial understandings; a predetermining factor of mathematical anxiety (Skemp, 1986). He stressed students' development of cognitive schema requires explicit guidance to ensure meaningful construction of webs of related ideas. Our aim was to encourage investigative thinking about the how and why of mathematics and its connectedness, as emphasised by ACARA (2010).

Developing dynamic thinking processes

The new curriculum encourages teachers to facilitate learning through "inquiry and active participation in challenging and engaging experiences" (ACARA, 2010, p. 126), in other words, puzzling over important mathematical ideas. However, research reveals that many teachers are unsure of what an inquiry process involves (Hartland, 2006; Hunter, 2008) or what working mathematically involves and looks like in practice (e.g. Anderson & Bobis, 2005; Cavanagh, 2006). Essentially, we believed a framework was necessary to structure reflective thinking and communication with and about mathematical ideas. After extensive research, we encouraged the preservice teachers to utilise three 'mathematics practices,' as advised by the RAND panel (Ball, 2003). The panel hypothesised that a fuller understanding of the dimensions of mathematical proficiency and supporting teachers to understand and translate the mathematics practices into classroom practices could lead to improving the quality of mathematics teaching and learning. These practices involve 'representing' mathematical ideas, using these representations to 'justify' the how and why of mathematical ideas, and then formulating a mathematical 'generalisation.' We anticipated that sense-making experiences of the mathematics and the practices would support preservice teachers to feel better equipped to continue learning, and to teach mathematics for proficiency.

Developing productive dispositions

To promote communal and individual inquiry requires recognition that knowledge and practices are always mediated within a sociocultural domain (Cobb, 1994; Lincoln & Guba, 2000). Hence, ED1491 was framed around the notion of "communities of practice" (Lave & Wenger, 1991, p. 41) and establishing a hospitable environment (Palmer, 1999). In a community of practice, the classroom community assumes the practices of the relevant discipline in similar ways that an apprentice assumes the practices of the trade. In a hospitable environment every idea is valued as an important contribution to the group's and to the individual's search for truth, no matter how off the mark it may seem. Thus, this paper examines the preservice teachers' perceptions about re-igniting productive dispositions in relation to the construction of mathematical knowledge, practices and dispositions in an online learning community of practising mathematicians.

Methodology

The participants were preservice teachers who had completed ED1491 in 2009 and were undertaking the second year external subject, *Mathematics Education for Early Childhood* (ED2093) (Klein, 2010). Interested in understanding how the learning experience impacted on their dispositions, some 'attitudinal questions' (Lankshear & Knobel, 2005) were posted on the discussion forum allowing voluntary responses to maximise the potential for reflective thinking. Of a total of 52 preservice teachers, 33 responded to this question: "Do you believe it is possible to reignite an interest in mathematics learning once a student has been turned off?" This presented productive data to help evaluate the subject and revise pedagogical and curriculum decisions. Recognising the influence of the sociocultural context, a qualitative content analysis (Lankshear & Knobel, 2005) was used to make valid inferences from the data, as intended by the participants. The anecdotes were categorised relating to knowledge, practices, and disposition development, and then analysed to draw out recurring themes about features of the learning context that might improve the quality of mathematics teaching and learning for proficiency. The data cannot be generalised to a broader population, yet highlight potential reasons for action (Burns, 2000). Replicability of the results would be difficult because understandings and learning contexts evolve and change daily.

Findings

The data revealed that of the 33 respondents, 29 believed that a productive disposition towards mathematics could be reignited; two believed it could not be, and two others believed it could be with the assistance of sensitive teachers. For clarity, the findings are delineated, although we recognise the interconnectedness of these sections.

Developing mathematical understandings

As Skemp (1986) explained, some participants blamed their mathematical anxiety on underdeveloped mathematical understandings. Two said that their anxiety strongly influenced their decisions to work in the early years. Another suggested that promoting inquiry may help to transform her abilities and view of mathematics:

- I don't think I will ever be passionate about maths, but doing this subject has made me realise, for the first time, why so many people are. I think the rest of us can find it intriguing and worthwhile if it is presented to us as fascinating puzzles waiting to be solved, and I wish I had been taught that way, because maybe my thinking would be more flexible now.

Whilst two others claimed that they dreaded mathematics, they too advocated more puzzling over ideas. They blamed the way they were taught for their anxiety and one recounts her experience as, "rules, procedures, do it this way, that's the wrong way, do it this way." Clearly, all four attributed mathematical anxiety to learning procedures not grounded in understanding because of minimal personal sense-making opportunities.

Another five commented that because their learning experiences were not engaging, they lost interest in mathematics learning. Two suggested that understanding relationships between mathematical ideas and applicability is important:

- I think the reaction of most of us to ED1491 shows that the way maths is taught can make a huge difference to students' feelings about the subject. For me, I know that one of my problems is making connections between mathematical concepts. I DO find it hard, yet this subject has made me realise that there is a fascinating world of knowledge, if I am prepared to make the effort – which I never was at school. Had it been presented to me in a way that emphasised the discovery of patterns and relationships, and which also allowed me to take ownership over my learning, I might have been more interested.

This comment suggests that the way mathematics learning is presented can impact on the development of conceptual understanding, appreciation of mathematics and willingness to persist in the learning, as ACARA (2010) and Kilpatrick et al. (2006) emphasise.

Structuring thinking processes

Interestingly, all of the participants, even the self confessed mathsphobics, reported in some way about the value of experiencing structured investigative thinking processes. They were learning new ways to think about and approach mathematical situations. For example:

- I think that the maths subject last year [ED1491] helped me revise things I hadn't thought of for many, many years. It even shed some light on new ways to do things which for me seemed easier than the procedures I had learned at school. Because we are focusing on an investigative approach to maths, it has enlightened me. I think perhaps this approach might just work for the kids too!!

Others related more specifically to the mathematics practices helping to structure the learning process. For example, one shares a practicum experience where she and a Year 2 student felt uplifted because the practices structured sense-making of some number relationships.

- His whole body language was negative and when there was a concept that he clearly did not understand he would start to rock on his chair, his shoulders would drop and he clearly switched off. After talking to his teacher I decided to go back to basics with him and went as far as making a number staircase from one to 10 so he could visually see what happened to a number when he counted on 1,2,3,0. The very first time he used the visual aid it was like a light was switched on. By being able to see that going up or down the staircase was like counting on or back he was able to answer simple number facts. His behaviour improved, his body language changed and he became a happy engaged and friendly student. It was extremely rewarding to know I had made a difference and was part of the process of reigniting his interest in mathematics.

This participant embraced an opportunity to practise what she had learned and makes clear the effectiveness of using visual representations to help the student justify an idea.

Many recognised that personal sense-making experiences helped to restore mathematical confidence and evoke a willingness to learn. For example:

- I was the student who had no confidence with math at all and the thought of having to do any kind of mathematical equation scared me to the point where I just wouldn't try. Since embarking on this degree, my interest has been reignited. I feel I am now equipped with different strategies to break down a problem and reach a conclusion, or many conclusions.
- We all thought we were bad at maths but now we are doing it differently, and it all makes

sense, we (or I) have realised it is quite fun and not so scary after all.

The reference to a conclusion relates to being able to justify the how and why of mathematics to formulate generalisations. In essence, both respondents were enthused by being able to validate the truth of mathematical ideas for themselves.

However, promoting change to encourage inquiry can present challenges for teachers. As pointed out in the vignette below, an inquiring classroom is often noisier and more active than the school may value.

- Allowing students to actually talk is a big issue in my daughter's school. There is still that notion that silence is good and that means children are learning (NOT). Children are often the best ones to explain to each other a problem or a question … they may view things from a completely different angle from us the teachers. It is so pointless making children complete a worksheet of math just for a red tick or cross, then to be glued into their math book and stuffed back in their desk drawer. There a maths lesson done!

Whilst relating to her daughter's learning experience, clearly this preservice teacher's mathematical inquiry has extended into active pedagogical inquiry.

Facilitating productive dispositions

Many others reflected on their own learning experiences and the types of learning environment they believe might support learning. They mentioned things such as, supporting students to be confident in 'having a go' without fear of embarrassment, listening enthusiastically to students, showing a genuine interest in students' learning achievements, and being passionate about mathematics and the learning of it. The comment below reveals that collaborative inquiry helped develop an understanding of what it means to be mathematically proficient for teaching and learning:

- My own mathematics learning was 'turned off' in Year 6. However, by participating in investigative tasks and discussion via the positive and respectful learning environment of ED1491 and ED2093, I now feel confident enough to 'puzzle out' mathematical ideas and relationships for myself. I finally feel like I am capable of 'doing' mathematics (thinking, reasoning and working mathematically). I believe that I will be a more effective and empathetic teacher for having reignited this interest. Consequently I hope I can promote an 'I can do it' attitude within all the learners in my future classrooms.

Hence, it appears that for these preservice teachers, a productive disposition depended on knowing and understanding mathematics in ways that support mathematical thinking and application, and proficiency involves all three aspects.

Discussion and conclusion

The findings discussed show that many preservice teachers' anxiety relates to lack of rigorous knowledge development. Yet, all of the participants believed that through using the mathematics practices to support and structure inquiry, their understandings were ameliorated and dispositions improving. In teacher education we can reignite, to some extent, for some students, for a time, a productive disposition. However, this disposition is malleable; it is not 'fixed' and will need continued support and refinement in professional development activities and collegial inquiry focused on 'proficiency in mathematics' for all. We recognise that 36% of the cohort did not respond and that other pressing concerns have arisen. First, the fact that two of the preservice teacher specifically chose early childhood education because of their fear of mathematics is alarming. These years are such an important phase of learning where the development of conceptual understanding will support successful learning in the future (Skemp, 1986). Further research is needed to understand how widespread these decisions are and what might be necessary to disrupt the cycle. Our hope is that these two preservice teachers' mathematical understandings and dispositions are altered over the four year degree to ensure they develop the understandings, abilities and dispositions to teach in productive and effective ways. Second, the preservice teachers all advocated puzzling over ideas, however, as one mentioned, promoting inquiry may not fit with what schools, staff and parents, value. Further research is needed to understand what support may be needed as preservice teachers attempt to implement ACARA's (2010) goals to ensure increasingly sophisticated proficiency in mathematics is developed in future generations.

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