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Preparing Preservice Teachers To Step Up To the Intentions of the Australian Curriculum, Mathematics: Revitalising the Mathematics and Demonstrations of Proficiency

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Abstract:
Key to the Australian curriculum in mathematics is the emphasis placed on the development of *proficiency*, a level of competence and expertise in the creative use, investigation and communication of mathematical ideas (ACARA, 2010). This implies that at the classroom level teachers and students will be engaged in novel practices, new ways of doing and using mathematics that reach beyond the procedural to value each and every student as an active, investigative participant in the construction of knowledge. Questions arise, though, as to how novice teachers can be encouraged to implement and sustain these flexible interactional practices, given their commonly expressed dislike of mathematics, their lack of content knowledge and of the reasoning processes that nourish its development. Sensitive to our students' need to be able to recognise themselves as teachers of mathematics, and our need to be able to recognise them as appropriately proficient for teaching, we have introduced a structured program that aims to build an appreciation of (a) mathematics, as a logical, integrated discipline with particular attention given to its inherent pattern and order, and (b) new ways of using and doing mathematics, specifically related to the reasoning processes of representation, justification and generalisation (Ball, 2003). While data presented in this paper demonstrate a measure of success in an on-line numeracy subject (ED1491), further research is needed to clarify the extent to which these particular experiences of a revitalised mathematics in teacher education can have lasting effects on classroom practice.

INTRODUCTION

Proficiency strands have been built into the Australian curriculum in an attempt to ensure "proficiency in mathematics skills is developed and becomes increasingly sophisticated over the years of schooling" (ACARA, 2010, p. 2). In today's complex world, proficiency in the use of mathematics is needed to equip workers for competition in a global marketplace where they need to know how to learn, adapt, create, communicate, interpret and use information critically (Commonwealth of Australia, 2009). In classrooms, students *demonstrating proficiency* would be creatively using, investigating and communicating mathematical ideas (ACARA, 2010). In society generally mathematical proficiency is core to a life well lived; persons lacking it are liable to miss out on a range of post-school and citizenship opportunities (Anthony & Walshaw, 2009). However, the imperative for proficiency draws attention not only to the need for the construction of rigorous and comprehensive mathematical knowledge, but also to the machinations of the learning process. It is in the learning process that students are enabled (or not) to step up to new ways of being proficient, of puzzling over mathematical ideas, of communicating and justifying their findings, of making generalizations; it is in the learning process, too, that prospective teachers are, partly at least, constituted as capable and generative (or not) teachers of mathematics. In our interactions with preservice teachers, we pay particular attention not only to the content, but also to the machinations of the learning process as we take these to be constitutive of future classroom practice.

The focus on *proficiency* in the Australian curriculum has prompted us to re-think and explore the fundamentals of a responsible teacher education program in mathematics. Proficiency signals the execution of a level of expertise in action, and in mathematics education draws attention to the theory/practice gap that endures. Preservice teachers establishing themselves as proficient mathematically and professionally must not only develop a robust knowledge base but also the flexibility of thought and the inclination to identify, interpret, and respond to others' mathematical ideas, difficulties and ways of thinking (Ball, 2003). From a poststructuralist notion of learners constituted in discursive practices, we have begun to reconceptualise what it means for primary school teachers to be mathematically and professionally proficient, and to imagine how our instructional practices might change to better support them in stepping up to the demands of the Australian curriculum.

SUBJECTIFICATION IN TEACHER EDUCATION

To be well positioned in any discursive field, let's say mathematics education, one has to have access to the powerful knowledge of the discourse, and be recognised as one capable of speaking and enacting its wisdoms. When one acts in agentic ways, one is able and willing to act beyond the taken-for-granted, to engage in novel and generative ways with concepts and ideas and take up new discursive practices. Exactly how teacher educators can best prepare their students for this sort of participation in classroom life is not clear, though a first step might be to carefully analyse the extant processes of subjectification in teacher education.

Currently teacher educators and researchers fall prey to the lure of the rational, autonomous (humanist) individual, and base their work on what prospective teachers don't know; the assumption is that new understandings will lead to new interactional processes. However, research (Foss & Kleinsasser, 1996; Nicol, 2006) demonstrates that the former does not necessarily result in the latter. From a poststructuralist perspective, we imagine that this is because even in inquiry-based pedagogies the prospective teachers undergo processes of subjectification as they did in school; there is no guarantee that they do not exit our programs having a sense of mathematical knowledge as absolute and unchangeable, and of themselves as not positioned very well at all in the discourse of mathematics education. For example, Kendra, a preservice teacher (Nicol, 2006; p. 32) lamented:

> Right now I am very frustrated ...We as beginning teachers need to know the math before we start hypothesizing, exploring, and understanding students. What I need is more concrete emphasis on the subject matter, rather than abstract thought about how kids learn...I still feel lost.

So within, yet also beyond the enduring struggle over content, a new imperative presents itself in that now it is important that prospective teachers not only learn about, but are constituted through, novel ways of doing and using mathematics that are compelling enough to mobilise application. These new ways of *being mathematical*, or *being proficient*, are different from the traditional ways because of their sensitivity to interactional power relationships, as well as the mathematics; a state of being proficient is premised on not only having the knowledge, but also the flexibility and inclination to apply this knowledge in diverse contexts. Key to bridging the knowledge/application gap is the notion that the sense-making process of knowledge construction must be initiated or owned by the learner; that is, the learner of mathematics must be seen as authoring or initiating personal sense in doing and using mathematical ideas. This authoring of a sense-making process is primary; it is constitutive and to the extent that preservice teachers find it convincing, it could be the catalyst to changed classroom practices in mathematics. However, old practices die hard, and as Raymond (1997, p. 574) reiterates: "Deeply held, traditional beliefs about the nature of mathematics have the potential to perpetuate mathematics teaching that is more traditional, even when teachers hold non-traditional beliefs about mathematics pedagogy".

We have used all that psychological research has taught us about learning and teaching mathematics and framed this with poststructuralist insights into the potential for change. Key to our program is the notion that preservice teachers can demonstrate proficiency in the classroom only after *being positioned as proficient* in teacher education. To this end, and ultimately for a revitalised classroom mathematics, we concentrate on three equally important interdependent variables: first, the construction of rigorous, foundational knowledge, centred on mathematical patterns and relationships (to step up they need the mathematical knowledge, the *muscle*); second, experiences of developing proficiency in active engagement in mathematics practices (Ball, 2003) (here they author and *exercise* the strategic thinking and reasoning processes that nourish the muscle and application) and third, framing all this, in recognising the *stepping up process* as constitutive, we do all that we can to make this process one where preservice teachers sense a developing proficiency for teaching. The theory is somewhat complex, and yet to be proven through longitudinal research, but our aim is that preservice teachers begin to sense that they can initiate and enact new interactional patterns, while developing the necessary content and interactive skills to do so.

THEORISING THE *STEPPING UP* PROCESS

At school, the preservice teachers experienced *ways-of-being* a learner (and teacher) that are constitutive of the person (and potential teacher) they are now. While much of the research and writing in teacher education is founded in the psychological and focuses on prospective teachers' anxiety and lack of knowledge, little thought is given to all that they *do* know that affects their engagement in teacher education and classroom practice. I refer here not to their relational and procedural knowledge as an intellectual product, but rather to the ontological dimension of *knowing* (Lather, 1991), about teacher/student power relationships and how things are done in teaching mathematics. This knowing, constituted through many years of lived experience, imperceptibly, invisibly, structures their participation and later teaching and is very difficult to change. Rational argument can shake, though rarely dislodge it. Even though many of the prospective teachers were poorly supported in learning mathematics and have exited school with an impoverished knowledge base, they fall back on the sorts of practices through which they were formed; they know no other ways-of-being mathematically. As Foucault commented: "people cling to ways of seeing, saying, doing and thinking, more so than to what is seen, to what is said, thought, or done" (Foucault, cited in Faubion, 1988, p. 175).

From a poststructuralist perspective, highlighting the constitutive power of classroom discourse and the inherent interactional practices, it can be seen that the preservice teachers have built a powerful arsenal in their knowledge of mathematics and how it is taught and learned. As learners themselves they largely took a passive role, waiting for the teacher to hand out worksheets, or textbooks, and show them the procedures to be practised and remembered. The relative positioning of the teacher and students, in relation to initiating and communicating mathematical ideas, was that the teacher authored knowledge and the student received and remembered it; knowledge of this positioning is inscribed in what they see as *normal* classroom practice. The challenge for teacher educators is to support the prospective teachers in turning this positioning on its head; in keeping with the imperative for proficiency, they must somehow help novice teachers enact practices that foreground the learners and their individual and active ways of making sense of, and communicating, mathematical ideas. Ideally, preservice teachers must step up to new interactional patterns in doing and using mathematics that become, to some extent at least, constitutive of their future practice as teachers of mathematics. Our pedagogical practices are premised on the assumption that preservice teachers' experiences of alternative discursive practices, being constitutive, can nourish and energise their stepping up to a new proficiency for teaching mathematics. However, caution is warranted, as alternative discursive practices can just as readily alienate, as seen in Kendra's (Nicol, 2006) comments above.

FACILITATING THE *STEPPING UP* PROCESS

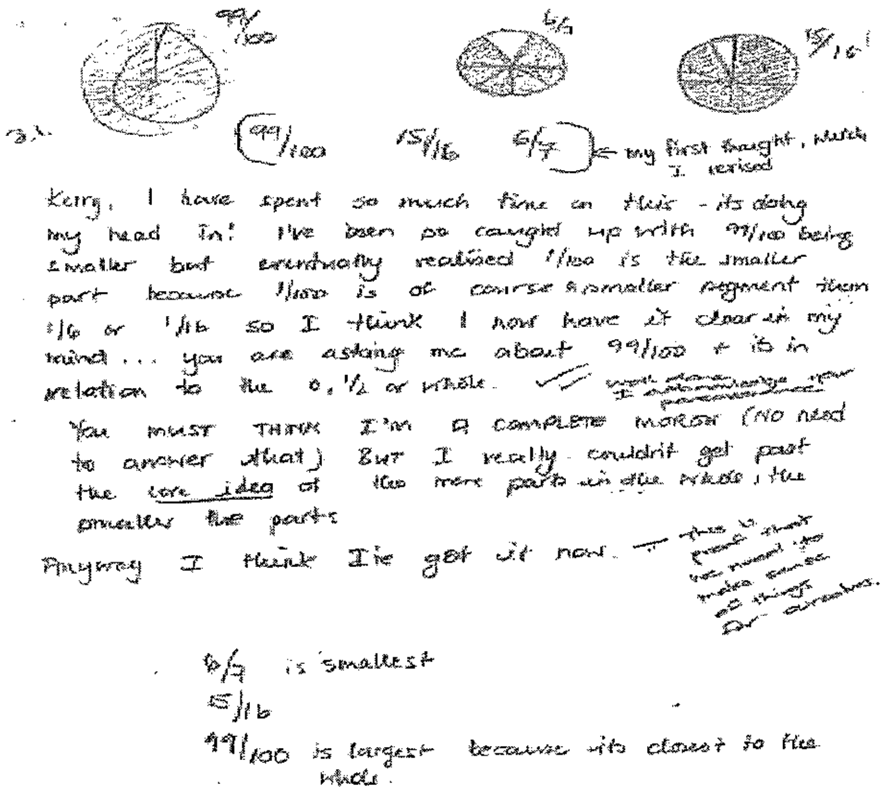
One component of the stepping up process is the construction of what we have come to think of as mathematical muscle; this is the *basic knowledge* of the language, written and oral and the procedural and relational knowledge that make up the very foundation of mathematics. Ball (2003, p. 37), for example, mentions how the "fluent use of symbolic notation" is a "critical practice" in developing proficiency.

To support the on-line delivery of the subject we prepared resources to scaffold the learning process; high levels of frequent and intense intellectual effort on the students' part were paramount and carefully monitored. The students had a professional workbook of mathematical investigations to promote physical engagement and hands-on learning experiences. A web-based program accompanied the workbook to enable them to revisit mathematical concepts, language and skills in an interactive manner:
http://www.soe.jcu.edu.au/subjects/ed1491/mod1/unit1/intro.shtml

From the comments below, taken from subject evaluation, it can be seen that many preservice teachers for the first time realise that mathematics has a logical structure and makes sense.

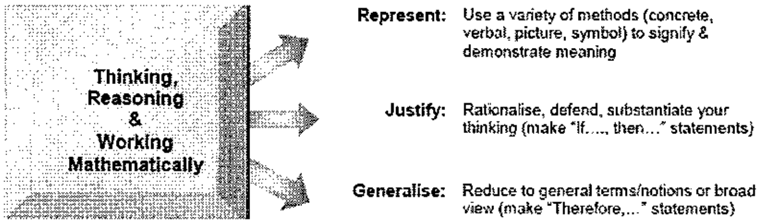
- I enjoyed the workbooks in this. As it provided opportunity to actually document what you knew and your understanding and from there feedback was provided on how you could better your explanations.
- The supporting web materials were great to check understanding. They provided a way to revise learning and test yourself as well as providing us with the start of a tool kit for the future.
- A very enjoyable course! Even if I had to think and use my brainpower a lot.
- The best aspect of the subject was the hands on investigations that were encouraged by the lecturer. Gave us skills we will certainly use in the classroom.
- I am really enjoying the activities so far and I am shocked to see how it all makes sense!
- I am from the old school where I was just given the rule with no questions asked. I just learned to do it, just the method or procedure. I didn't have to know why. I am really enjoying the challenge and the deeper understanding that this subject is providing.

Hoping that the preservice teachers can "be sensitised to the beauty of mathematics, the ability to see the whole and to find harmony and relationships" (Mann, 2006, p. 236) we emphasise the underlying orderliness and regularity, the structure of mathematics, by each week focusing on investigations focused on particular mathematical relationships. In this way we anticipate that our students have a scaffold around which to focus their understanding and later teaching; for example, in investigating the relative 'size' of common fractions, they learn to focus on the relationship of each fraction to 0, ½, or 1. In the example below a student struggles over her investigation into whether $^{99}/_{100}$, $^{6}/_{7}$ or $^{15}/_{16}$ is the largest fractional piece:



A second component of ED1491 to which we pay particular attention is the quality of the *learning process* which is crucial for two reasons: students' development of robust and comprehensive content and pedagogical knowledge, and for the opportunity it affords the preservice teachers to experience new interactional practices that exercise and energise the mathematics. The lifeblood of the mathematics classroom is the thinking and reasoning, the communication of ideas, the creative use of mathematics to solve problems and undertake investigations; we attempt to stimulate intellectual engagement and encourage the preservice teachers to struggle over important ideas (DETA, 2008; NCTM, 2007; Savery & Duffy, 2001; Hiebert et al., 2000).

The Australian curriculum encourages teachers to facilitate successful learning through "inquiry and active participation in challenging and engaging experiences" (ACARA, 2010, p. 126). However, research reveals that many teachers are unsure of what an inquiry-based approach involves (Hartland, 2006; Hunter, 2008), or what thinking and working mathematically involves or looks like in practice (e.g. Anderson & Bobis, 2005; Cavanagh, 2006). So that the prospective teachers might be enabled to structure a mathematically rich learning context for their students, we utilise the three 'mathematics practices,' as advised by the RAND Mathematics Study Panel (Ball, 2003). We model and have our preservice teachers engage in practices of robust inquiry: (1) *representing* the mathematical idea, (2) finding and *justifying* a solution, and (3) forming a *generalisation* (Ball, 2003). In this way preservice teachers come to realise the importance of supporting learners in inquiry, as they are actively involved in constructing mathematical ideas and practices.



Having a clear structure to follow, and having learned and practised interactional teaching strategies, many preservice teachers indicated they were keen to implement investigative tasks in the classroom.

> ➢ I was a kid who sat in the double morning maths lesson yawning so much she had tears running down her face! I hated the monotony of it, I remembered the formula and sum (as witnessed last week, now forgotten) and did quite well at tests but I was bored and struggled with the problem solving element when it was introduced in high school. I would have stand up arguments with the teachers through sheer frustration. After being introduced to the inquiry method of learning maths from first year there have been many light bulb moments and I am now enjoying the challenge of learning again for understanding. I guess feeling like a capable learner through this new method has reignited my interest!

To support and scaffold learning, aware of *positioning within power relationships*, we do not focus on anxieties or deficit, but on a rigorous program of high quality, interactive instructional materials, regular and comprehensive feedback and strong and sustained interpersonal relationships. A productive disposition is "the tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics" (Kilpatrick et al., 2006, p. 131). Moving beyond fear and anxiety, we focus on what our students do know, and in our view, each and every student is considered to be a capable and valuable participant in the on-line learning community. As Anthony and Walshaw (2009, p. 11) state: "Instead of trying to fill weaknesses and gaps, [effective teachers] build on existing proficiencies, adjusting their instruction to meet students' learning needs. Such teachers are responsive both to their students and to the discipline of mathematics".

> ➢ All of the learning experiences provided throughout the semester have helped me gain a new appreciation (and confidence) for mathematics.
>
> ➢ Our lecturers did everything possible to make sure you could understand and pass the subject. It was not just about end results, it was about learning and understanding so that we could become great maths teachers. It made us realise that there is more to maths than problems on a page.
>
> ➢ This subject was excellent in format and content. The way the subject was structured made it extremely relevant to our future profession as teachers. More BEd subjects should be like this in terms of its relevance to future teaching.
>
> ➢ Thank you for the dedication and time you have put into this subject. I have had to relearn many ideas, but in doing so have learned that the world of mathematics is truly amazing!
>
> ➢ My own mathematics learning was "turned off" in Year 6. However, participating in investigative tasks and discussion via the positive and respectful

learning environments of ED1491 (numeracy education) and ED2093 (second year 'methods' subject), 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 mathematics teacher for having reignited this interest. Consequently, I hope to promote an "I can do it" attitude within all the learners in my future classrooms.

> ➢ It just so happens that I was great at learning procedures and remembering rules and remembering facts. So I'd always thought I was pretty good at maths... until last semester in ED1491 when we were asked to explain the how and why of things! After exploring these ideas myself, I feel much more empowered mathematically to teach and help others construct their own knowledge of these key mathematical relationships.
>
> ➢ Last year in ED1491 I learned ways of working things out that I'd never heard of before! That's why I said that I think that all the procedures we learned at school, and have now forgotten, made us think we are no good at maths but in actual fact it is only the procedures we have forgotten and we need to use investigative thinking to work out different methods that we understand better and may be easier for us to remember.

- ➢ I have enjoyed this subject externally. I feel the discussion board online is a huge help as [author] lets the students discuss the problem before she gets involved to help us.

THE SUCCESS OF THE *STEPPING UP* PROCESS

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) reports on the apparent decline in Australian students' numeracy skills and he suggests the way forward is to improve the quality of classroom teaching. However, Professor Rammage (cited in Brown, 2009), who has worked extensively with teachers and preservice teachers, believes phobic dispositions are a continuing problem; others (Brady & Bowd, 2005; Wilson & Thornton, 2006; Stephens, 2000) agree, suggesting that underdeveloped understanding is the cause. Whatever the cause, many of our preservice teachers still need to develop "increasingly sophisticated and refined mathematical understanding and fluency" (ACARA, 2010, p. 126), and effective mathematical practices that enable "logical reasoning, analytical thought processes and problem solving skills" (p. 126). To this end we have revitalised our teaching according to a couple of principles that we take to be paramount:

First, we prioritise the doing and using of robust mathematics; using the analogy of a ball game, we strive to ensure that each and every student steps up to physical and intellectual engagement for the maximum time possible. We throw the ball, often in the form of investigations or conjectures to prove or disprove. Mathematics is not a set of correct answers but a method of reasoning, a way of figuring out a certain kind of system and structure in the world (MCEETYA, 2008). From the student quotes above, it can be seen that many of the students take up the ball and find the intellectual engagement and strategising worthwhile; from their assignments and portfolios of investigations we note that many of them are gradually establishing more sophisticated expressions of mathematical proficiency. Although the finessing of high levels of quality engagement is enormously time consuming, we will continue to discourage a reliance on superficial and low level proficiency as this is what has presented us with our most serious problems in the first place.

Second, we priortise the positioning of the preservice teachers and are very aware of the vulnerability they feel in the stepping up process; they are expected to learn what seems to them to be a new mathematics, a new ball game, yet they know that they need to be comfortable and proficient in enacting its rules and strategies with future students. Although many of the preservice teachers remain reticent and cautious, we attempt to scaffold a stepping up process as best we can. Other than the core of mathematical proficiency, the building of mathematical muscle and the energising mathematics practices, we support the students themselves in their personal process of becoming (more) proficient. In discussion groups and in comments on assessments the tone is always one of expectation and encouragement, with an emphasis on the preservice teachers' capacity to speak and be heard, to initiate and articulate meaning (Davies, 1991). Despite the previous positioning of many of them as non-players in the old ball game, we attempt to not only give them access to new strategies and practices, but to encourage their application through their developing, to some extent at least, a sense of themselves as proficient for teaching. The aim is to have preservice teachers exit the program not only with the flexible and proficient use of mathematics at their fingertips, but also with a sense of themselves as ones who can and should actively make sense of, rather than take for granted, the mathematics and the learning needs of their students.

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