Designing Opportunities for Prospective Teachers to Facilitate Mathematics Discussions in Classrooms

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How prospective teachers can best be prepared to teach effectively in mathematics classrooms is a topic of current concern. In this paper, we describe our exploration of ways in which prospective teachers were supported to translate what they learnt in mathematics methods classes into pedagogical practice. We illustrate how the use of discourse routines, enacted in iterative cycles of guided rehearsals, disrupted previous beliefs about teaching and learning mathematics and led to them more confidently respond in pedagogically appropriate ways.

Introduction

Over the past decade, New Zealand, like many other countries in the Western world, has undergone significant reform in mathematics education. Consistently reform efforts have centred on teacher professional development as a way to improve the quality of teachers' mathematical understandings and pedagogical practices. For example, the New Zealand Numeracy Development Project (NDP) (Higgins & Parsons, 2009) aimed to enhance teacher knowledge of student numerical knowledge and strategy levels while also promoting a New Zealand wide vision of mathematics classrooms in which pedagogical instruction centred on students' sense-making through interactive discussions. Facilitating such rich mathematical discussions requires significant pedagogical skills which studies (e.g., Lampert, 2001; Sherin, 2002) reveal even able teachers may struggle with. Therefore if proficient teachers exhibit difficulties enacting the pedagogical practices promoted in reform programmes how then can novice prospective teachers learn these complex pedagogical actions so that they are enacted in classrooms with confidence? In this paper we address ways in which discourse routines may be employed as both practical and intellectual tools in instructional activities designed to scaffold prospective teachers to learn to respond in pedagogically appropriate ways to the complexity and uncertainty of mathematics discussion.

Conceptual Framework

In the next section we will look at current research literature which describes changes being enacted in pre-service programmes to better support prospective teachers to translate what they learn in their mathematics methods classes into practice. The second section will outline research findings on the role of productive mathematical discussions in classrooms and the pedagogical strategies teachers use to enact them.

Pedagogies of Enactment

In recent times there has been increased discussion and research on ways prospective teachers can be prepared to teach effectively in mathematics classrooms. This discussion has been prompted by a growing disquiet that pre-service teaching programmes may have limited influence on prospective teacher's classroom practice (Kazemi, Franke, & Lampert, 2009). Hammerness and colleagues (2005) attribute this situation to problems encountered

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in enactment and complexity. They explain that prospective teachers in methods classes are given a vision of appropriate teaching and learning but developing the required pedagogical skills is left to be learnt in the interactive situation of the field where the complexity of the situation may be over-whelming. To address this situation Kazemi and her colleagues draw on what Grossman and McDonald (2008) term pedagogies of enactment to illustrate through approximations of practice how prospective mathematics teachers can be supported to learn the 'what and how' of teaching but also learn 'to do' interactive mathematics teaching.

Pedagogies of enactment suggest it is not sufficient to equip prospective teachers with knowledge of the importance of mathematical discussions or the discourse strategies teacher use to enact them—they also need to know how to do things in practice and be able to enact them in interactive ways (Ghousseini, 2009). Ghousseini argues that effective development of prospective teacher's pedagogical skills requires "teacher education pedagogy that is grounded both in *action* and in *reflection*" (p. 149) and which develops a disposition of inquiry. Ghousseini illustrated the positive outcomes afforded a group of prospective secondary teachers in a mathematics methods course when they were provided with opportunities to practise parts of interactive teaching. To reduce many of the complexities of enactment, modelling and rehearsing was used. The teacher educator modelled a mathematics lesson with them in the role of students and as it proceeded it was carefully deconstructed and reflectively analysed to make visible the many discourse moves. The lesson was followed by designed opportunities for them to engage in rehearsal of discourse moves using fictional classroom scripts. The rehearsals called upon them to role play and make decisions about applying the discourse moves in responsive ways which progressed the collective mathematical thinking within productive mathematics discussions.

Productive Classroom Mathematics Discussions

Discussions are an essential teaching and learning component of current New Zealand mathematics classrooms although in this context mathematical discussions differ markedly from those of traditional classrooms. Whereas in more traditional settings the teacher's key role is to deliver instructions and information then quiz for correct responses, the advocated focus of discussion is now on students' thinking and reasoning rather than correct answers (Nathan & Knuth, 2003). The teacher takes the role of facilitator and engages the class in sustained reasoning about the students' current mathematical constructions (Chapin, O'Connor, & Anderson, 2003). Through these reasoned mathematical discussions teachers lead students to engage in a range of complex mathematical practices (Lampert, 2001). These include such practices as making conjectures, explaining, justifying, and representing possible problem solutions, and opening them up for other members of the community to analyse and critique and make connections. Significant teaching skills are required to ensure students are able to use these disciplined means of reasoning while at the same time maintaining fidelity with mathematics as a discipline (Boerst, Sleep, Ball, & Bass, 2011). Teachers are called upon to interactively make spontaneous judgements related to the reasoning and at the same time respond in ways which are both respectful and maintain focus at depth on key mathematical learning.

Teachers use a range of different practical and pedagogical strategies to manage successful facilitation of productive mathematics discussions. These include an explicit focus on the development of classroom participation structures and enacted sociocultural and mathematical norms (Sullivan, Zevenbergen, & Mousley, 2002). For example, Hunter (2008) describes the use of a Communication and Participation Framework which teachers used to scaffold a group of diverse learners to reach carefully reasoned mathematically

understandings. Other studies (e.g., Boerst, Sleep, Ball, & Bass, 2011; Kazemi, Franke, & Lampert, 2009) outline the positive outcomes when teachers use specified practices to reduce the degree of in-the-moment responses teachers must make. Smith and Stein (2011) describe the practices "as skilful improvisation" (p. 7) and outline how their use allows teachers to anticipate, plan for, and sequence student contributions in ways which further the lesson's mathematical agenda. These key practices include *anticipating* possible student responses, then *monitoring* them as they are constructed, *selecting* students to present their responses, *sequencing* them and *connecting* them to key mathematical concepts. Another set of studies (e.g., Chapin, O'Connor, & Anderson, 2003) outline how teachers use a set of talk moves to ensure that the mathematical discussion is productive. These include teacher and student revoicing, teacher initiated requests that a student repeats another student's contribution, elicitation of student reasoning, teacher request to add on and teacher wait time. Ghousseini (2009) describes these talk moves as "purposeful and disciplined *discourse routines*" (p. 149) which teachers establish and orchestrate to support mathematical learning.

Method

The participants were prospective teachers enrolled in a one-year post-graduate pre-service primary teaching course. The 22 participants in this study self-selected into the mathematics education option within the Classroom Inquiry paper. The overall aim of the paper was to engage prospective teachers in a process of 'teaching as inquiry'. The participants had completed the first semester mathematics methods course and were enrolled and part way through their second mathematics methods course. They had also completed nine weeks of teaching experience over two practicum placements. The two participating teacher educators, both experienced classroom mathematics teachers and teacher educators, co-taught the Classroom Inquiry mathematics option, and the first author taught the methods courses with the participants.

The focus of the first methods course was placed on students developing understanding of relevant mathematical content knowledge. In the second methods course the focus shifted towards developing the students' classroom pedagogical knowledge. As part of this course the students discussed and analysed research papers which specifically studied and described teachers' use of talk-moves (Chapin, O'Connor, & Anderson, 2003), the five practices (Smith & Stein, 2011) and they were also introduced to the Communication and Participation Framework (Hunter, 2008).

In the Classroom Inquiry mathematics option the enactment of the instructional intervention aimed to provide the prospective teachers with opportunities to practise and rehearse key aspects of managing mathematical discussions in productive ways. Within the university setting the prospective teachers engaged in a range of instructional activities. These included providing them with opportunities to predict a range of possible solution problems for a rich task in a peer group and using the task to teach and manage a discussion with a small group of their peers while being monitored by the teacher educators. Other activities included them reading and analysing different scripts and discussing how these related to teacher use of the five practices (Smith & Stein, 2011) and talk-moves (Chapin, O'Connor, & Anderson, 2003). The foci of the instructional activities then shifted to a school setting. The prospective teachers in pairs were each allocated groups of six 9 and 10 year old students. In four iterative cycles they were required to plan mini lessons based on rich problems provided by the teacher educators. As part of the university rehearsal phase they were required to devise a plan based on a protocol that used the five practices of group discussion (Smith & Stein, 2011) and included questions to incorporate to enact specific talk

moves. In the classroom enactment phase involving the four lessons one of the pair taught the lesson and the other video-recorded it. Following each lesson the video record was reviewed by the pair and the talk-moves discussed and analysed. The assessment for the prospective teachers' paper required them to prepare a video presentation of their learning from their experiences as an inquiry teacher.

The complete cycle—from rehearsal to classroom enactment and reflection— generated multiple forms of data. These included the prospective teacher's planning documentation, video records of lessons, and a final video compilation of their learning journey. They also kept a reflective journal in which they were required to record regular entries. The journal entries, in particular, provided the data for this paper.

Results

The initial journal entries illustrated the dilemma the prospective teachers (PT) encountered between their recent practicum experiences and the theory and practice vision they were encountering within the context of the mathematics methods course and the Classroom Inquiry mathematics option. As one stated:

> PT 1: I was at a stage of teaching where I was confident in my abilities and what I was "doing" in the classroom, but I had not questioned what an effective classroom looked like and what learning actually was and I was not sure how teachers and learners could be partners.

A central theme of these journal entries showed that the prospective teachers (PT) were grappling with their past experience as students in mathematics classrooms in what was described by one PT as "taken for granted pedagogical perspectives". Their previously experienced quiet and orderly classrooms had taught them that the teacher held a key position as imparter and validator of the knowledge:

> PT 17: My own experiences of learning at school and university had "taught" me that learning was about receiving and regurgitating information. Successful learning was quiet and orderly, with the teacher maintaining control; the teacher's role was the boss.

Others, while acknowledging the benefits which could accrue through inquiring into pedagogical practices that could facilitate productive discourse between students and students and teacher at the same time described their own feelings of trepidation or inadequacy. One talked about enacting such practices as "daunting", another described his own learning process "as a voyage with detours, speed bumps and maybe the odd shipwreck". In their reflective statements many PTs noted that this was a difficult journey which required a shift in disposition towards that of inquiry into their own pedagogical practices that was frequently marked by acceptance of the need to change. As one stated:

> PT 5: One issue I will need to think about is teacher change—a teacher needs to be open-minded and also willing to make mistakes—like me many teachers have difficulties with this factor.

A clear focus in the initial set of reflections was that the PTs were seeing themselves as learners—learners who faced difficulties and challenges associated with their early experiences of considering and enacting interactive mathematics teaching.

Beginning to Notice and Respond

The influence of previous mathematics learning situations continued to thread through all the PTs second set of journal entries recorded after the first teaching session in school. These earlier schooling experiences and previous practicum experiences continued

to benchmark their experiences during this first teaching session in school and shape the prospective teachers post lesson reflections. For example, one PT questioned her role in previous mathematics teaching on practicum:

> PT 11: As a teacher of mathematics throughout my practicums I believed I was providing a rich lesson because we had materials to use, great warm up games and the students were getting the right answers but where was the mathematical discussion? What I notice now is that I was giving students too much support, too much guidance towards just getting the right answer.

In the second journal entry prospective teachers' commentary moved to include a direct focus on their role and obligation to create productive opportunities for children's learning. Many PTs identified the difficulties they had in their first school session with allowing students space and time to reason and take responsibility for their own learning "when you are just itching to steer them in the right direction". A common theme was their need to be in control:

> PT 23: A challenge for me is my desire to rescue students when they are going down the wrong path or are stuck in their thinking. If students are to take responsibility for their own learning, explore the problem, and make sense of it…I must allow them the space to make mistakes, have incorrect answers and work through their thinking.

All PTs recognised the importance of mathematical discussions for sense-making. They noted how it supported the students to deepen their mathematical understandings and also how it gave them access to each child's sense-making:

> PT 19: I am developing my ability to notice what the students are saying and using their discussions and justifications…through noticing I get an understanding into where the children are at and can use this in my planning and assessment.

However, the complexities involved in enacting productive mathematics discussions continued to concern them. Some talked about the challenge of having all students engage and participate while others described their need to further develop good questioning skills.

> PT 2: My thinking about mathematics discussions is challenged by the degree of 'with-it-ness' required for a teacher to perform the role of moderator and orchestrator well. In order to develop into this type of role I need to confront my tendency to drop back into direct teaching and the propensity to want to rescue children by providing too much overt guidance if I see them struggling to adapt to the role of questioner and protagonist at first. I recognise that both of these instincts are rooted in my early learning experiences, in which permission to make mistakes was not extended from teacher to students. One learned to do maths by rote and that mistakes were not considered to be part of the learning process.

The PTs acknowledged the value of the rehearsal phase with the instructional activities in the university setting. While they felt this phase supported their growing ability to plan for interactions using talk-moves, they recognised that to use them well, required time and practice in a more authentic setting.

> PT 10: I have had a chance to try out some of my own talk moves during lectures with my classmates, and really see how difficult it is. I still need more time to practise my talk moves and have some more time to ask good questions. I still find it difficult to anticipate some of the 'incorrect' answers and strategies that children come up with but I think a lot of this will be through experience and understanding how children think.

Evident in the second set of entries was growing awareness of themselves in the facilitation role. They recognised the tools they had available in the form of the five practices and the talk moves but knew they were novices in their use of them.

Building Confidence to Notice and Respond

A significant shift is evident in the third set of reflective entries. For all PTs there was a growing recognition of their own strengths as facilitators and partners in students' learning. The iterative cycle of rehearsals had provided them with tools to use in the 'here and now' of classroom interactions. Clearly evident is their recognition of the importance of listening and noticing and how they could access student reasoning through questioning:

> PT 23: I notice that my ability to listen and notice student's learning is proportional to the degree to which I use questions to revoice, sequence and in the process make student's thinking visible. I appreciate that these practices are a large part of active listening and that I need to make (for the time being) conscious efforts to use talk moves intervention in order to direct and focus learning on the big math ideas and concepts and to recognise when students are using them.

Although repeated practice had supported them to make the talk moves part of their developing repertoire of pedagogical skills, many described a need to purposely remember to use them "until they become second nature and natural":

> PT 10: I have found the ability to listen and notice student learning through the talk moves is not that difficult but for me it has to be done deliberately and consciously, for now at least.

The video records were important reflective tools which provided the PTs with "more detailed monitoring of the students' learning". This included insight into not only the students' correct reasoning but also their misconceptions, which emerged in the interactions. Through use of the records the PTs were able to analyse their strengths and weaknesses and establish their next learning goals:

> PT 3: In my teaching session I touched upon the surface of my students' reasoning of the problem. After watching my video over and over it was evident that I was not doing enough revoicing, having students repeat other students' contributions and wait time. So that became my next deliberate focus in my plans and I included questions.

Many PTs described confidence in their skills to anticipate and monitor student reasoning but outlined how linking the different students' reasoning to big mathematical ideas in coherent ways challenged them. However, they acknowledged the importance of this next step:

> PT 1: Two of the practices which need more work are sequencing of strategies and the connections..This signifies the important way in which I build connections with the strategic ways that students are working out the problem as well as the big mathematical idea. It also can help take the students understanding to another level by exposing them to a more abstract and multiple ways of thinking and understanding..

The third set of journal entries illustrated that the PTs had developed a vision of productive discourse and their role as a facilitator and were confident that with focused practice they could develop the pedagogical skills to enact it.

Becoming Confident to Notice and Respond

The final set of journal entries, completed after four school visits, demonstrated both PTs awareness of and growth in capability to facilitate productive discourse in practice. They now recognised how rich discussion supported them to listen, notice, and respond to students' reasoning and how discussions supported their students developing rich and deep understandings. They described how the many opportunities to rehearse (both in the university and school setting) had provided "practice in increasing our

automaticity of using talk moves". They had "become more natural" and served as an important tool to assist them to manage the flow of mathematical talk:

> PT 19: Although we had been taught about discourse based instruction in [mathematics methods] class it is not until I tried it out for myself that I had begun to learn the skills...my ability to think quickly has improved and I am able to deal with things going 'off the script' more easily. This has improved my ability to respond to students' contributions and I am sharper when making observations and able to assimilate the unexpected.

Many PTs acknowledged the key role of effective questioning as a tool which was "helpful in navigating the uncertainties of interpreting students' thinking" and as a way for all students to access the mathematical reasoning:

> PT 10: The use of effective questioning has also been an area of learning, particularly to ensure that students' learning becomes visible to me (for assessment) and to other children (for learning).

Although all PTs were cognisant of the pedagogical skills they had gained during the inquiry they indicated that they knew they were on a learning journey and this needed to continue:

> PT 19: The next learning step for me is to continue to use mathematical discourse so it becomes second nature. By continuing the use of effective questioning, talk moves, and the five practices is going to enable me to gain clarity. Within this context a community of learners develop and students become very much a main contributor of their own learning. I need to ensure that the lessons lend themselves to the big mathematical idea that we want students to learn and make sense of.

In the final set of journal entries the PTs' key focus shifted more towards what they considered was important for their students as learners of mathematics. Their journal reflections demonstrated that they as teachers had learnt that rich mathematical understandings emerged through carefully facilitated mathematics discussions which focused on key mathematical ideas. Most importantly, because talk moves had become part of their pedagogical repertoire they were able to better manage more complex situations as they arose.

Discussion and Conclusions

This paper has illustrated how innovative prospective teacher education programmes can through use of what Kazemi and her colleagues (2009) term approximations of practice, better equip prospective teachers 'to do' interactive mathematics teaching. The evidence provided, supports Ghousseini's (2009) contention that it is not sufficient for prospective teachers to be told about the importance of mathematical discourse or the pedagogical strategies teachers use—they also need to know how to enact them, in structured ways which provide them with success.

The opportunities to plan, rehearse and reflect on their facilitation of mathematics discussions afforded the prospective teachers space to reconstruct their views on teaching and learning mathematics. Rehearsing and reflecting on the actions had affordances which supported them to break from the traditional frames of reference described by Nathan and Knuth (2003) and engage in actions which they would not have habitually used. The integration of the five practices (Smith & Stein, 2011) and the talk moves (Chapin, O'Connor, & Anderson, 2003) provided scripted scaffolds that the novices needed to develop as part of their pedagogical repertoire. In this process, the iterative rehearsals afforded them a reduction in the complexity of mathematical interactions. This resulted in

them being better able to notice and respond in ways that enhanced collective mathematical reasoning. Of importance in the process was the grounding of the teacher education pedagogy in both action and in reflection (Ghousseini, 2009). The approximation of practices enacted in the rehearsals and the reflective analysis of the video records and recordings in the journals supported the prospective teachers to assume a stance of inquiry through which they gained knowledge of the importance of productive mathematical discourse as a tool to deepen the students' mathematical understandings.

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