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Learning to teach mathematics through inquiry: a focus on the relationship between describing and enacting inquiry-oriented teaching

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Abstract This article is based on one of the several case studies of recent graduates of a teacher education programme that is founded upon inquiry-based, field-oriented and learner-focussed principles and practices and that is centrally concerned with shaping teachers who can enact strong inquiry-based practices in Kindergarten to Grade 12 classrooms. The analysis draws on interviews with one graduate, and on video data collected in his multi-aged Grade 1/2 classroom, to explore some of the ways in which this new teacher enacted inquiry-based teaching approaches in his first year of teaching and to consider his capacity to communicate his understanding of inquiry. This article presents implications for beginning teachers' collaborative practices, for the assessment of new teachers and for practices in preservice teacher education.

Keywords Inquiry-based learning and teaching · Beginning teachers · Communicating beliefs

Introduction

Research shows that teachers' pedagogical beliefs do not necessarily match their classroom practices (e.g. Herbel-Eisenmann et al. 2006; Raymond 1997). In this literature, it is most commonly reported that beginning teachers' classroom practice lags behind (in terms of sophistication) their espoused beliefs and their ability to describe good practice (Barrett et al. 2002; Britzman 1991; Raymond 1997), and that what teachers learn in mainstream teacher education, and from educational research, does not transfer to the classroom setting (Kennedy 1997; Lampert and Ball 1998; Wilson and Goldenberg 1998); in other words, that beginning teachers can 'talk the talk' before they can 'walk the walk'. Whitehead (1929) would refer to such beginning teachers as having 'inert' knowledge—they can *talk* about an idea or construct, but it does not guide their *action* in new settings. In contrast,

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in this article, I develop the argument that, in particular forms of teacher education (such as the inquiry-based programme in which the teacher described in this article participated), it may be the case that teachers learn to 'walk the walk' of inquiry-based teaching and learning before they develop a sophisticated ability to 'talk the talk'. This article is based on one of several case studies of recent graduates of our teacher education programme—a programme that is founded upon inquiry-based, field-oriented and learner-focussed principles and practices and that is centrally concerned with shaping teachers who can enact strong inquiry-based practices in Kindergarten to Grade 12 classrooms. The analysis reported here draws on interviews with one graduate (Daniel[1]), and on video data collected in his multi-aged Grade 1/2 classroom, to explore some of the ways in which this beginning teacher[2] enacted inquiry-based teaching approaches that he had learned about in his teacher preparation programme in his first year of teaching and to consider his capacity to communicate his understanding of inquiry.

Theoretical framework—a phronetic approach to teaching and learning

Despite the extensive efforts of preservice teacher education (Darling-Hammond and Bransford 2005), technical modes of teaching, which valorise prediction, measurement and control in the classroom, still dominate K-12 education in North America. In the area of mathematics instruction, for example, research conducted in the United States by Jacobs et al. (2006) and others (e.g. Hiebert and Stigler 2000) has shown that current teaching approaches are more like the kind of traditional teaching reported for most of the past century (Cuban 1993) than the kind of teaching promoted by mathematics educators and mathematics education leadership organisations such as the National Council of Teachers of Mathematics (e.g. NCTM 2000). Despite this gloomy portrait, and as Watzke (2007) indicates, many researchers have proposed that teachers undergo positive developmental changes as they gain classroom experience. Many such developmental theories draw on Fuller's (1969) 'concerns theory', which posits three developmental stages: first, a concern for self (such as concerns for receiving good evaluations from administrators, and acceptance by colleagues); secondly, a concern about the task of teaching (such as worries about instructional methods and perceived deterrents to the delivery of curriculum, etc.); and thirdly, concern for impact (such as concerns for guiding, challenging and meeting the needs of diverse students). Fuller proposed that these concerns follow a hierarchical pattern, with teachers advancing through the three stages as they gain experience. Whilst some studies confirmed this assumption, Watzke (2007) noted that multiple beginning teacher studies, including his own, have rejected this chronology and instead have consistently identified the prevalence of beginning teachers' concerns for impact. Such research, whilst it may confirm that the new generation of beginning teachers are primarily concerned about student learning and are capable of complex and student-oriented thinking (Burn et al. 2000), does not provide evidence that such articulated beliefs and concerns are actually reflected in the beginning teachers' classroom practices. This article presents one example of a beginning teacher enacting teaching practices inspired by a philosophy—*phronesis*—that explicitly rejects a technical perspective on teaching.

[1] All the names (beginning teacher and school students) used in this article are pseudonyms.

[2] As the research reported here spanned a period of time covering the participant's experiences in preservice teacher education and in his first year of teaching, I use the term 'prospective teacher' to refer to the experiences of the participant during his preservice teacher preparation programme, and the term 'beginning teacher' to refer to his experiences in a school classroom as a full-fledged teacher.

As Coulter and Wiens (2002) note, phronesis does not easily translate into English, but a common translation, and one adopted by the teacher education programme in which the beginning teacher featured in this writing participated, is practical wisdom. Phronesis is a particular kind of knowledge—one oriented to action, and specifically ethical action, action oriented to the good (Lund et al. 2006; Coulter and Wiens 2002; Ricoeur 1992; Wall 2003). Phronesis, or practical wisdom, in its various forms, is now emerging as an important re-orientation for practice across disciplines (Sullivan and Rosin 2008). Whilst the various enactments of phronesis in practice differ somewhat in their emphases, they each contrast sharply with the dominant technical rationalist approach to teaching. As Dunne (2005) notes, a technical approach to teaching is one that

> seeks to extract from [practice] a rational core that can be made transparent and replicable. Typically, this entails disembedding the knowledge implicit in the skilful performance of the characteristic tasks of the practice from the immediacy and idiosyncrasy of the particular situations in which it is deployed, and from the background of experience and character in the practitioners in whom it resides. Through this disembedding, it is supposed that what is essential in the knowledge and skill can be abstracted for encapsulation in explicit, generalisable formulae, procedures, or rules—which can in turn be applied to the various situations and circumstances that arise in the practice, so as to meet the problems they present (p. 375).

Conceptions of teaching grounded in Aristotle's notion of *phronesis* instead emphasise the importance of judgment in context. Hence, in a phronetic frame, less emphasis is placed on the applying of generalised knowledge (such as knowledge of efficient routines for pacing lessons) and more on the ability to bring general and particular—theory and practice—'into illuminating connection with each other' (Dunne 2005, p. 376). 'This requires perceptiveness in [the] reading of particular situations as much as flexibility in…'possessing' and 'applying' the general knowledge' (p. 376).

Flyvbjerg (2001) also notes that phronesis is oriented towards praxis or thoughtful action, and adds that phronesis concerns itself with addressing three fundamental questions—Where are we going? Is this desirable? What should be done (in other words, what is best to do for these students, in this context, with this subject matter, etc.)? These are questions that reverberated throughout the academic spaces in which the teachers in this study dwelt during their teacher education programme. The theme of striving for the good in practice runs as an undercurrent to the programme, and hence becomes an imperative for many of the graduates as they begin teaching.[3] In addition, Ricoeur's (1992) formulation of ethical intention as aiming at the good life with and for others in just institutions guides the actions of the teacher educators responsible for leading the programme and formulating its curriculum (Lund et al. 2006). The programme embraces phronesis, 'and in doing so attempts to prepare teachers [who] can dwell within the rough ground of experience, appreciate its complexity and deep interpretability, and respond ethically' (Phelan 2005a, p. 62). In other words, the programme attempts to develop a capacity for *discernment* (Dunne and Pendlebury 2002). 'Discernment speaks to a teacher's capacity to see the significance of a situation, to imagine various possibilities for action and to judge ethically

[3] Continuing longitudinal research with Daniel and the other graduates is revealing that despite challenging contexts in which these graduates have been called upon to practice in their beginning years and despite sometimes implicit and/or explicit rejection of their ideas by more experienced colleagues around them in the schools, their frame of reference for judging how to act in relation to their students has continued to be the phronetic philosophy of the programme. Publications detailing these findings are currently in process.

how one ought to act on any given occasion' (Phelan 2005a, p. 62). A sense of ethical purpose is, then, central to the work of teaching (and teacher education), and this imperative is taken seriously in the programme.

Given these philosophical underpinnings, a phronetic approach to teaching therefore calls forth from practitioners a set of capacities and practices that differ strongly from those valued within a technical rationalist frame. This cluster of practices is commonly referred to as an *inquiry-based* approach.

Inquiry-based practice

Inquiry-based practice, in various guises and with multiple descriptors, is emerging as a popular approach to teaching and learning in many fields, particularly those in professional domains (see e.g. Hayes 2002; Phelan 2005b; Plowright and Watkins 2004; Shore et al. 2008). Many of the practices now clustered within the term inquiry-based have a basis in Dewey's philosophy of learning, and, in the field of mathematics education, can be traced through the constructivist movement and are reflected in the 'reform' movement spearheaded in North America by the US-based National Council of Teachers of Mathematics (NCTM 2000). Inquiry-based practice is a slippery concept, and it is variously interpreted and represented in the literature (Aulls and Shore 2008). As Hayes (2002) notes, inquiry is often conflated or used interchangeably with other terms that describe similar teaching practices, such as hands-on learning, generative teaching, and constructivist practice.

Advice for teachers attempting to enact inquiry-based practices is now beginning to proliferate and here, also, definitions of inquiry are quite disparate. A publication produced for Alberta teachers by Alberta Learning draws on the work of the Galileo Educational Network, an educational organisation based at the University of Calgary, to define inquiry as 'the dynamic process of being open to wonder and puzzlements and coming to know and understand the world' (Alberta Learning 2004, p. 1). The document further suggests that 'inquiry-based learning is a process where students are involved in their learning, formulate questions, investigate widely and then build new understandings, meanings and knowledge' (p. 1). Elsewhere, inquiry-based practice is recognised as 'inquiry into authentic questions generated from student experience' (National Research Council, cited in Hayes 2002), or as 'the process of searching for patterns and relationships in the world around us' (Moscovici and Holmlund Nelson 1998).

Given these descriptions of inquiry, we can anticipate that inquiry-oriented teaching rests upon a particular set of teacher competencies and dispositions, though it is not easy to discern a coherent or agreed set of such capacities from the emerging literature. Not surprisingly, most of the literature on teacher competence works from a technical frame (such teaching is, after all, much easier to measure against standardised objectives). In this literature, strong performances on standardised testing instruments are often used as the fundamental measure of teacher capability (see e.g. Benjamin 2002; Mertler and Campbell 2005; Pecheone and Chung 2006). Such measures privilege technical modes of teaching—modes that in themselves privilege efficient routines that 'aspire to exercise total control…defined in terms of optimal effectiveness in achieving ends, and optimal efficiency in realising most benefit with least cost' (Dunne 2005, p. 374). In contrast, scholars and teachers educated in and through phronesis value other practices in their analyses and enactments of teaching, and these practices and dispositions tend to be less amenable to measurement on standardised scales.

The kinds of knowledge, practices and dispositions typically attributed to inquiry-oriented teachers include:

- a level of comfort with ambiguity and uncertainty (Lampert and Ball 1998; Phelan 2005a, b);
- understanding the provisional nature of knowledge (Dunne 1997; Lampert and Ball 1998; Phelan 2005a) and the complexity of the teaching/learning relationship (Phelan 2005b);
- responsiveness to students (Lampert and Ball 1998; Moscovici and Holmlund Nelson 1998);
- a commitment to exploring student thinking as well as skill in probing and making sense of students' ideas (Lampert 2001; Lampert and Ball 1998; NCTM 2000);
- knowing how to 'teach for understanding', including fluency in teaching with manipulatives, guiding small-group work, capitalising on students' multiple solution strategies, and so on (Lampert and Ball 1998; NCTM 2000);
- the ability to understand and draw out the deep structure of the discipline so that learners learn to reason and connect ideas (Puntambekar et al. 2007) and
- a commitment to building a community of inquiry in the classroom (Alberta Learning 2004; Phelan 2005a), as well as a host of social and personal capacities such as care and concern for others.

In determining the extent to which the beginning teachers in the study enacted inquiry-based practices in their beginning teaching, the analysis of data described in the following sections draws on these core principles of inquiry-based teaching and learning.

Context of the study

Daniel, the participant on whom I focus in this article, engaged in a two-year Bachelor of Education After-Degree programme at the University of Calgary that is founded on inquiry-based, learner-focussed and field-oriented principles and practices (see Phelan 2005a, for a broader description of the structure and guiding philosophy of the programme). Within this programme, prospective teachers are taught in small groups, usually between 15 and 22, collaboration is encouraged, the entire programme is non-graded and much of the curriculum is case-based. Prospective teachers complete three major field placements—two in school settings and one in a community or workplace setting. They are in schools continually during the programme, sometimes for 2 days per week and sometimes for full immersion, but whether they are in school or on campus the focus of the programme's teacher educators is on integrating theory and practice so that each informs the other. The description of the programme that follows reflects the programme structure that was in place when the data collection for this study was undertaken. Since that time, as the programme itself is constantly evolving, some changes to the organisational structure, though not to the principles and philosophy, have taken place.

In the first semester of the programme, which focusses on the theme of *Learning and Teaching*, all the prospective teachers (secondary and elementary, together) participate in weekly Case Tutorials, with written case studies focussing on learners and learning and teachers and teaching. Prospective teachers (again secondary and elementary combined) also participate in weekly Professional Inquiry Seminars designed to help them interrogate their assumptions and biases and begin to formulate their identities as beginning teachers. Prospective teachers are in schools 2 days per week for half the semester, and in a

Community/Workplace placement 2 days per week for the remainder of the semester—this latter element designed to help them explore and begin to understand the diversity of spaces in which educational experiences take place in our society. A weekly, two-hour, on-campus Field Inquiry Seminar in the first semester supports and guides the work of the prospective teachers in their various field placements, and here prospective teachers are separated into elementary and secondary routes. Prospective teachers are encouraged to understand their time in schools and classrooms as a text to be interpreted and as a form of inquiry into what it means to learn to teach rather than as a space in which to simply practice being a teacher, and it is perhaps this emphasis more than any other that gradually, over the 2 years of the programme, helps prospective teachers learn to teach phronetically. In the second semester of the programme, within the theme *Curriculum Content and Curriculum Contexts*, prospective teachers continue in their school placements 2 days per week, with an additional week-long immersion near the end of the semester, and this work continues to be supported by a weekly Field Inquiry Seminar on campus at the university. Prospective teachers participate in two weekly, three-hour Case Tutorials in this semester (again separated by specialist route). In the third semester of the programme, within the theme *Praxis*, prospective teachers participate in a major field placement in a school (typically in a different grade division, socio-economic region of the city, etc., than their first-year placement). Prospective teachers are in schools 4 days per week for much of the semester, and this work is supported by a weekly, three-hour, on-campus Field Inquiry Seminar that also integrates a Case Tutorial component, wherein prospective teachers are asked to develop 'living cases' derived from their practices in schools. Within third semester, prospective teachers also experience a full-time, three-week immersion in schools. In the final semester of the programme, focussing on the theme *Integration*, prospective teachers engage in three weekly, three-hour, on-campus components—a Professional Inquiry Seminar which further develops the aims of the first semester Professional Inquiry Seminar, a Case Tutorial, and a Special Topics Seminar, all of which engage both elementary and secondary route prospective teachers together. The Special Topics Seminar requires prospective teachers to complete a research-based inquiry project that includes opportunities for them to return to their schools in the role of action researcher (Benke et al. 2008) to further analyse issues of teaching and learning in context. This seminar is also the only space in which the prospective teachers have choice in the programme, and many opt to engage in deeper study of the various curriculum areas they may be asked to teach in their beginning practice in schools.

The participants in the research study were prospective teachers who opted to participate in my own Special Topics Seminar in the final semester that focussed on teaching mathematics through inquiry. Participants in the seminar, and in the research, were drawn from early childhood, elementary, and secondary routes in the programme. During the seminar, prospective teachers were exposed to current research on teaching mathematics through inquiry, and the weekly seminars were also structured around mathematics tasks that required participants to engage in learning mathematics through inquiry.

The research study

The purposes of the research study were to explore the experiences of prospective teachers learning to teach mathematics within an inquiry-based teacher education programme and to study whether and how these teachers enacted what they had learned in their teacher preparation programme in their first year of teaching. In order to conduct the research,

I videotaped 12 of the 13 three-hour teaching sessions[4] during the final semester of the programme in the Special Topics Seminar, focussing the camera both on myself and on small groups of volunteer prospective teachers (12 in total) as they worked on the mathematics and pedagogy tasks. I also interviewed nine of these volunteers once they had left the programme in the Spring (the remaining three being unavailable to continue with the research after the end of the teacher education programme). I then followed three of these beginning teachers, as they embarked upon their first year of teaching, and continued to interview them during the year.[5] I and/or my research assistant also videotaped their mathematics teaching throughout the year, averaging nine videotaped lessons per teacher between September and June. We also conducted task-based interviews at the end of the year with some of the children who had been part of the classroom videotaping to gain more information about the children's mathematical understanding. Daniel was one of the three beginning teachers in whose classrooms I videotaped throughout the first year of teaching. He has been chosen as the focus of this article not because he is unique but because his experience, talk, and classroom practices are consistent with those of all three beginning teachers I followed. Whilst I might, therefore, have focussed on any one of the three, Daniel's case highlights the particular challenges for a beginning teacher whose first teaching assignment is in a teaching environment in which his/her practices are clearly different to those of a more experienced grade-team partner.

Data analysis proceeded through an iterative process of viewing and reviewing the video data and supporting evidence (such as field notes and copies of school students' work on classroom mathematics tasks), following the approach described by Powell et al. (2003). Initially, the videotapes were viewed in their entirety to get a sense of their content and context, without imposing a specific analytical lens. In the second stage, the video data were described through writing brief, time-coded descriptions of each video's content. The aim was both to map out the video data for further analysis and to become more familiar with its content. In the third stage, the data (videotapes and coded notes) were reviewed to identify 'critical events' (see e.g. Maher 2002). The fourth stage involved analysing and coding these identified critical events to create rich and detailed theoretical descriptions of critical events in the process of learning to teach of a number of prospective teachers, over various time periods. The fifth stage of analysis involved examining closely these analysed and coded critical events to identify and construct a storyline to 'discern an emerging and evolving narrative about the data' (Powell et al. 2003, p. 430). For Daniel, this storyline has at its core the disparity between his ability to describe inquiry and his more sophisticated ability to enact inquiry-based practice in his classroom. In the final stage of data analysis (still in progress), the storylines established for each research participant in the fifth stage are reassembled to produce cross-case written narratives that speak to general themes in the data and address other aspects of the nature of learning to teach through inquiry. Elsewhere, I focus in more detail on some of my own teacher education practices

[4] The first session was not videotaped so that prospective teachers had time to understand the purposes and methods of the study and make informed choices about whether to participate in the research.

[5] The three beginning teachers were 'chosen' for accessibility reasons rather than because they had shown particular skills in, or understanding of, inquiry-based practice. For instance, though some beginning teachers volunteered to be videotaped in their first-year classrooms, their school principals would not allow the research to proceed (citing it as too much pressure for a beginning teacher). In addition, I was unable to include in the school-based component of the research those volunteers who accepted teaching positions in remote locations in distant provinces as well as those who did not gain a full-time teaching contract until after the school-based research component had begun.

within this inquiry-based programme (e.g. Towers 2007), and on the issue of the sustainability of beginning teachers' inquiry-based practices in current K-12 schooling structures (Towers 2008), but here I present a description and analysis of one beginning teacher's practices and discourse to explore both the extent to which this beginning teacher was able to enact inquiry-based teaching approaches in his first year of teaching and his capacity to communicate his understanding of inquiry.

Daniel's experience

Daniel's classroom practice

At the conclusion of his teacher education programme, Daniel, an elementary-route student with a background in theatre arts, secured a position in a multi-aged Grade 1/2 classroom. He demonstrated inquiry-based classroom practice from the very beginning of his first year of teaching. Analysis of the videotapes recorded in Daniel's classroom reveals that he employed a range of teaching strategies consistent with strong inquiry-based practice, such as using varied and interesting prompts to engage learners, drawing from commendable sources when planning for teaching (such as the journals of the National Council of Teachers of Mathematics), using good children's literature and taped stories as prompts for mathematical investigation, using children's own suggestions as prompts for mathematical investigation, often incorporating the use of manipulatives in his classroom, connecting the mathematics to other curriculum areas the children were studying, encouraging the children to work together to solve problems, showing genuine interest in students' alternative solution strategies, and encouraging mathematical reasoning and argumentation. Table 1 offers examples of the kinds of mathematical tasks that Daniel set for his class and the kinds of teaching strategies he employed.

It is beyond the scope of this article to provide extensive transcripts from the lessons that might serve as evidence of Daniel's classroom practice. Instead, I provide here a description of one lesson that shows features that were typical of problems, events, practices, and norms in Daniel's classroom throughout the year. This particular lesson occurred in April near the end of the school year, though similar problems, conversations, and ideas were in play from the very beginning of the year. Daniel began the lesson by reviewing what the children remembered about a story they had recently read about the history of counting. In the story, a shepherd boy had counted the sheep in his care by collecting small black pebbles—one for each sheep. When the bag of pebbles became too heavy, the shepherd boy painted some of the pebbles red (with berry juice)—one red pebble for every 10 black. In this way, he was able to reduce the number of pebbles he had to carry in his bag. In time, the flock grew and the boy extended his system by colouring a pebble green for every 100 sheep. In class, as the students re-told the story, Daniel represented the various numbers of sheep in the story by drawing black, red, and green dots on chart paper. The task he then set for the class was to show different ways of representing any given number with coloured dots. As an example, Daniel showed how 112 could be written as one green dot (100), one red dot (ten) and two black dots, or as one green dot and 12 black dots. Daniel then extended the problem context to consider how the 112 sheep could be represented if they were located in two different fields (e.g. 51 + 61). As he set the students to work in pairs, he asked for three representations of the given number using dots—(1) the shortest way to represent the whole number, (2) an alternative way to represent the whole number and (3) lots of ways the sheep could be distributed between

Table 1 A sample of Daniel's mathematical tasks and teaching strategies

Task description	(Non-exhaustive) Sample of teaching strategies employed
Bicycle/tricycle problems	
Within a rich story context about a bicycle shop (not described in full here) students are asked to solve various arithmetic problems over several days. Examples include: (1) If the shopkeeper wishes to construct five bicycles and four tricycles, how many wheels must he order to assemble the bikes? (2) How many handgrips must he order (given each bike needs two handgrips)? (3) If the shopkeeper is sent 12 additional wheels by the supplier, how many additional bicycle (or tricycle) frames does he need in order to use up the wheels? (4) If the shopkeeper wishes to construct bicycles *and* tricycles with the extra 12 wheels, how many of each could he build?	Encouraged struggling learners to use manipulatives to represent the wheels and handlebars Encouraged students to work in groups to solve the problems Ensured alternative solution strategies were shared and discussed Encouraged mathematical reasoning and mathematical community building by using a story context, by showing that he valued hearing students' strategies, and by requiring students to explain their process, etc.)
Reams of paper problem	
Driven by student interest in the amount of paper used in their school, students were invited to calculate the number of reams of paper used by their class over the year (given the number the teacher ordered and the number still available in the storage area), and then to estimate how the paper could have been used/distributed (e.g. by dividing in various ways such as by the number of children or by the number of rows or clusters of desks)	Encouraged students to work in groups to solve the problem Ensured alternative solution strategies were shared and discussed Encouraged mathematical reasoning through the structure of the task Connected the mathematics to environmental issues that connect with the Social Studies and Science curricula Drew upon students' own ideas as a prompt for exploration
Toothpicks problem	
Given four toothpicks, how many different ways can they be arranged (with the limitation that they can only touch at a vertex and at 90° or 180°)?	Offered manipulatives to aid reasoning and recording Ensured alternative solutions were shared and discussed Encouraged mathematical reasoning and mathematical community-building through the structure of the task and by encouraging mathematical argumentation about what counts as a 'different' solution

Table 1 continued

Task description	(Non-exhaustive) Sample of teaching strategies employed
One hundred hungry ants problem	
Using a children's story (Pinczes 1993), Daniel introduced the concepts of arrays, multiplication, division, and factors. The story concerns ants walking to a picnic, initially in single file, and continually being rearranged by one of their number into larger rows so that they can get to the picnic faster. Arrays used in the story include 1×100, 2×50, 4×25, and 5×20. After listening to/reading the story, students were given a box of 100 paperclips (which they were to use to represent the 100 ants) and asked to check that their box actually contained 100 paperclips (which in itself produced some interesting and sophisticated counting strategies), then figure out if the book had shown all the possible ways the ants could have marched to the picnic in (evenly distributed) rows	Offered paperclips as manipulatives to represent ants Encouraged students to work in groups to solve the problem Ensured alternative solutions were shared and discussed Encouraged mathematical reasoning through the structure of the task
Squares and triangles problem	
Students were required to determine whether squares or equilateral triangles (or both) can be constructed given particular perimeters. Students were given the following perimeters to investigate: 15, 16, 18, 20, 21, 23 and 24 cm	Encouraged students to work in groups to solve the problem Ensured alternative solution strategies were shared and discussed Encouraged mathematical reasoning by showing that he valued hearing students' strategies, and by requiring students to explain their process, etc.)

two fields. As the class was a multi-aged grouping, Daniel differentiated the task by having different starting numbers for the two grade groupings (though he used flexibility in having students work at a level of comfort regardless of grade level assignment). For this particular task (though not always), Daniel chose to have the students work with another student at the same grade level. Whilst the class was working on the problem, Daniel circulated around the room, settling the groups and ensuring everyone could begin the task and then he knelt by the desks of successive pairs of students, encouraging, directly teaching, asking questions, and monitoring students' progress and understanding.

In this lesson, for the small-group time, I focussed the camera on two Grade 2 students—Marlon and Ophelia. This pair began with the number 126. They quickly drew one green dot, two red dots and six black dots and moved onto representing this whole number in different ways. Ophelia's second representation of 126 was 12 red dots (12 tens) and six black dots (6 units). Marlon's second representation was one green dot (100), one red dot (1 ten) and 16 black dots (16 units). This pair then progressed to the 'field' scenarios and, with a prompt from Daniel, began with two sheep in the first field. Both Marlon and Ophelia represented two black dots (for the two sheep in the first field) and one green, two red and four black dots for the remaining 124 sheep. However, Ophelia included the conventional '+' symbol between the two black dots and the green dot, and between the red dots and the black dots of the 124. She also introduced the adaptation of writing the conventional numerals (2 and 124) beneath each representation of dots and colour-coding each digit to match the colour of dots it represented. Marlon also appropriately coloured dots for 2 and 124, adding a '+' symbol between them and ending his expression with '= 126'. Marlon, in addition to colour-coding dots also showed a distinct tendency, throughout his work, to use different sizes of dots (large for hundreds, medium for tens and small for units).

Both students, sometimes working individually and sometimes drawing on each other's ideas, created several other representations before Daniel, visiting their desk and recognising that they needed further challenge, suggested that they set challenges for each other by each giving the other a starting number of sheep in the first field. Marlon and Ophelia engaged enthusiastically with this challenge, Ophelia first suggesting 20 sheep in the first field and Marlon responding with (and representing) 'ten reds and six blacks'. Ophelia asked, 'Is there an easier way to do that'?—pondered the problem for a moment—and decided 'one green and six blacks'. They each represented this scenario, showing both these ways of constructing 126.

When Daniel called the class back to the carpet to discuss their work, he gathered students' differing representations of 52 (the initial number assigned to the Grade 1 students) and 126, again drawing these on chart paper. During this plenary, many students showed that they had strong number decomposition skills. For instance, in reviewing a 'two fields' scenario offered by a Grade 1 student who suggested that for 52 sheep in two fields "you could have three red dots and one black dot in Field One [31] and two red dots and one black dot in Field Two [21]', a second student, when asked for an alternative way of splitting the 52 sheep said, 'you could take one of the red dots from the three red dots in Field One and have five black dots on that side [Field One] and five black dots on the other side'. Daniel used this opportunity to show that this new scenario (26 in each field) had created a situation in which decomposition would be needed in a two-digit addition in column format. He wrote 26 + 26 in column format and connected the 12 that appears in the algorithm (6 + 6) to the 12 black dots in the two fields represented on the chart paper and reinforced how these came from (and can be recombined to make) a red dot and two black dots.

This classroom example shows some features that were typical of Daniel's classroom:

- active student participation in both small-group and whole class activity,
- mathematics tasks drawn from a story scenario that captured students' interest and connected to prior instruction,
- curriculum differentiated in the classroom not by separate, leveled activities and tasks but by adaptations to, and multiple entry points for, the same task,
- a flexibility in being able to extend a task (e.g. the device of two fields and the game in which Marlon and Ophelia participated near the end of the session),
- connections made between conceptual understanding and facility with procedures (e.g. two-digit addition algorithms),
- use of tasks and tools that enable students to glimpse the deep structure of mathematics,
- demonstrating interest in, and valuing, students' alternative solutions and strategies, and
- encouraging mathematical reasoning.

This classroom description also shows that a sophisticated level of fluency with number concepts was expected from these Grade 1 and 2 students.

Daniel's talk about practice

Despite the above evidence of his inquiry-oriented classroom practice, Daniel was one of the prospective teachers who voiced the greatest concern about his knowledge of, and preparation for, teaching. When I interviewed him five weeks before the start of his teaching, he was unsure how he would begin and vague about how to translate his vision for teaching through inquiry, and his learning in the teacher education programme, into reality. He reflected on how nervous he was about the first week of school, how he felt under-prepared to develop a literacy programme for young children, and was not able to describe to me how one might teach early childhood students through inquiry, though it was clear that this was how he believed it ought to be approached. In our first interview, I asked Daniel what he was most looking forward to as he prepared for his first year of teaching. His initial reaction was to switch focus to talk about what he was most nervous about instead:

> Daniel: [You mean] what am I most nervous about?….There's a lot of things [*laughs*]. First of all the first week of school. I mean, I don't know, I can't even think about what's going to happen….I guess when I get there I'll figure it out. Erm, and I'm just nervous that 'will I do a good job'? You know, is it going to work? I mean, I have a vision of how it should work, but it never works out that way. You just sort of have to go with the punches and go with how your classroom sort of moulds together.

Finally, Daniel described what he was most looking forward to:

> D: I guess…those moments when they do mould together and things do happen, you know? [*Pause 4 secs*] And hopefully they will.

As we talked about what he learned in the mathematics course with me in his final semester, we start to see (in the next excerpt) a glimpse of how Daniel is thinking about pedagogy—though he still reported not knowing 'how to teach Grade One'.

> D: Well…I guess if I didn't have the experience I did in the [mathematics course] I wouldn't really understand. I would have sort of gone back to my memories of high school math or junior high math, which is, you know, memorise, learn, memorise….But

> since I've had this experience in the [*names the Programme*], I've kind of looked at it differently and even though I…probably don't know how to approach math in Grade One and Two in all the ways, I know that it's better to approach it where the children discover it on their own than to tell them. [*Pause*]. Although sometimes you need to tell them if, yeah, but, erm, I haven't really…thought about the details of how I'm going to go through that process, but I know that's how it needs to be done.

We also see here some of the tension in Daniel's description of inquiry-based learning and teaching. He struggles to articulate the relationship between children 'discovering for themselves' and the role of the teacher in 'telling', rendering this relationship somewhat dichotomous. The relationship between exploration and telling, as much of my own and others' research has shown (Towers 1998, 2002; Towers and Davis 2002; Chazan and Ball 1999; Davis 1994; Lobato et al. 2005; Smith 1996) is, of course, a core dilemma of teaching that remains unresolved; therefore, it is not surprising that Daniel would struggle to traverse this terrain verbally in an interview, though I know many who would expect a more nuanced descriptive ability by the time prospective teachers graduate, as Daniel had, from 2 years of education in inquiry-based teaching and learning. This, though, is precisely my point. Many of these beginning teachers were tongue-tied when asked to describe the nuances of inquiry-based teaching; yet, they were capable of *enacting* a nuanced understanding of inquiry-based practice in their classrooms.

Of course, there were areas of Daniel's practice that showed the usual beginning teacher inexperience, such as some of his classroom management strategies, but he himself commented on this during one of our interviews and described how he had recognised the problem as one that was 'contagious' in his classroom and had made changes to re-stabilise things, though he was at pains to point out that he was seeking a balance between the extremes of chaos and too much control and that he really did not want the students to be 'scared to do anything' and that he still wanted them to be able to 'express their ideas'.

We also addressed the issue of collaborating with other teachers—an element of Daniel's teacher preparation programme that was emphasised both in descriptions of inquiry-based teaching and as a core element of the structure of our case-based curriculum. Given this, I had anticipated that Daniel would value and seek out collaboration in his school, but his response rather surprised me. As I describe more fully elsewhere (Towers 2008), Daniel admitted that he had resisted his team partner's vision of 'team planning' and 'team teaching' for mathematics. He indicated that the other Grade 1/2 team teacher whose classroom adjoined his wished to split the two grades and teach them separately for mathematics so that instruction could focus on 'facts and addition'. Daniel had strongly resisted this philosophical approach to mathematics teaching, and thus avoided 'team' planning and teaching for mathematics, preferring instead to keep his class together and work in more investigative ways on rich problems that could support the curriculum, and breadth of ability levels, of both grades of students. In actively choosing not to 'team' with the other Grade 1/2 teacher for mathematics, I do not believe that Daniel was rejecting collaborative practice as a stance but rather protecting what he saw as an important feature of his mathematics teaching—the opportunity to present flexible contexts and problems to students that he felt could accommodate both grade levels of students, rather than split the classes and teach the two grade levels separately for mathematics so they could focus on 'facts'.

In discussing with me this power struggle within his grade team, Daniel framed the problem in terms of his inability to convey his vision for teaching mathematics through inquiry in ways that would enable his more traditional team partner to understand:

D: [She] isn't very comfortable with sort of the way I see math being taught. She's very, erm, she trusts that I know what I'm talking about. I don't know if I really do know what I'm talking about [*laughing*] but, erm, she sees my vision. [*Pause 4 seconds*] Well, maybe she doesn't. She sees that I *have* a vision, but she doesn't see what it is…you know what I mean?

Daniel adopted the blame for this breakdown of communication between his team partner and himself:

D: It's partly my fault because I can't really describe [*pause 2 secs*] *how* I'm wanting to teach it. I just sort of have an idea, and I can't/I mean in order for me to really describe it to her I'd have to just show her sort of the learning I did over in [the university] and all that, and all the papers I've read from there and…my inquiry project I did last year…and…I mean I could, I guess, steer her in the right direction and say 'this is sort of the latest thinking on teaching math in a constructive manner', or this and that, but I can't really explain to her how to do it.

When I asked how he felt about needing to try to explain new teaching approaches to experienced teachers, we see Daniel's characteristic beginning teacher's uncertainties coming to the fore:

D: Erm, yeah, I guess it was a bit nerve-wracking. 'Cos how do I know if I'm doing it right, right?

Though he cannot find the words to describe inquiry-based teaching to his colleagues, and does not feel completely confident that his approach is the 'right' one, his decision to resist splitting his multi-aged class for mathematics represents an act of courage from a first-year teacher. Whilst he was hesitant in his ability to *describe* good inquiry-based practice in mathematics, he had the confidence to take a stand to *practice* in the way he thought would best benefit his students, even in the face of resistance—a characteristic that is evident in the data for several of the other beginning teachers in my study and that is developing as a consistent theme in the continued longitudinal research I am conducting with these teachers. However, we also can see here how Daniel's inability to describe inquiry-based practice interfered with his capacity to help his teaching colleagues understand what he was attempting to achieve through inquiry and hence prevented the Grade 1/2 teachers from coming together to learn from one another.

Discussion and implications

Aporia: 'a perplexing difficulty' (Oxford English Dictionary)

Whilst I have used Daniel's experience of learning to teach through inquiry as an example in this article, his case represents a common theme in the data collected during the study. Daniel, and most of the other beginning teachers, conveyed a tentativeness in their talk about inquiry-based learning that presents, for me as a teacher educator, an aporia or perplexing difficulty, in that their observed classroom practices belied their articulated concerns of under-preparedness and their relatively unsophisticated ways of describing inquiry in mathematics. If, as teacher educators working in an inquiry-based frame, we are concerned with shaping strong inquiry-based practices in beginning teachers' classroom teaching, why should it matter that those beginning teachers seem unable to articulately

describe their vision for teaching through inquiry? Herein lies the aporia. Graduating beginning teachers whose ability to describe good practice lags behind their capacity to enact it leads to several challenges.

Challenges for collaborative practice

As Daniel's case reveals, the inability to fluently describe a vision for inquiry-based teaching can lead to a set of dilemmas that centres on the difficulty of collaborating with other teachers who do not share the same vision for teaching. Daniel made the difficult decision to withdraw from collaborative planning and teaching efforts with the more experienced teacher in his grade team, not because he does not value collaboration but because he wished to protect what he saw as an important feature of his mathematics teaching—the opportunity to present flexible contexts and problems to students that he felt could accommodate both grade levels of students. In terms of a phronetic approach to teaching, we might see Daniel's action here as the exercise of discernment and good judgment. As Dunne (2005) notes, what is called for in situations of complexity is 'receptivity to the problem…rather than keenness to master it with a solution' (p. 377) and Daniel's resistance shows that he is receptive to the challenge of teaching through inquiry.

It is clear that his inability to describe inquiry-based practice, though, interfered with his capacity to help his teaching colleagues understand his vision for teaching through inquiry and hence prevented the Grade 1/2 teachers from coming together to learn from one another. Daniel is in a difficult position—caught between a vision for teaching through inquiry that he feels is right but cannot articulate fluently and a system populated by veterans who value straight talking, ready and familiar answers, and tried and tested methodologies. Daniel's response to this dilemma was to assume the blame for the lack of collaboration in his grade team, and attribute the problem to his inability to articulate his vision.

If beginning teachers, educated in and wishing to practice inquiry-based teaching and learning, are not to have their initial attempts at inquiry-based teaching filtered through more traditional teachers' lenses of 'what works with these kids', then they must be given the opportunity and support to grow their practice. In this frame, Daniel's decision to resist his team-partner's vision of team-teaching might be seen as, in fact, a sensible one. Like many first year teachers, not all of Daniel's attempts to teach through inquiry were smooth, and a team-teaching approach (with a sceptical teacher) immediately puts the novice teacher under pressure to make an inquiry approach 'perform' better than a traditional one. This is an unreasonable expectation for a newcomer. Being 'teamed' with a sceptical veteran is, therefore, a particularly undesirable assignment for a beginning teacher attempting to teach through inquiry.

Collaborative practice is increasingly seen as an important element of developing a school or classroom culture that supports student learning and teacher change (Krainer and Wood 2008), and a teacher's willingness to collaborate with others is perceived as a valuable disposition (Alberta Learning 2004; Britt et al. 2001; Government of Alberta 1997; Kluth and Straut 2003). Hence, a beginning teacher who seems to resist collaboration or team-teaching may be perceived as 'difficult' to work with and, therefore, not the kind of person principals want to have on their staff. As we have seen, Daniel had good reason to resist collaborative planning and teaching in his particular context, but his case suggests that further research is needed to help us better understand the nuances of beginning teachers' experiences of trying to enact and sustain inquiry in a context where they encounter resistance.

Many beginning teachers do indeed abandon research-based practices in favour of the more common traditional practices they see around them in the schools (Allen 2009), but Daniel's case shows us that inquiry-based practices can be maintained, though perhaps at a cost (in this case, lost opportunities to collaborate with more experienced teachers as there was likely much Daniel could have learned from his team partner if they could have found a meeting ground). Research that specifically seeks to explore ways in which collaboration can be encouraged such that beginning and experienced teachers can learn from one another, despite holding opposing philosophical views about teaching, would be particularly valuable since these are the conditions under which teachers like Daniel have to try to practice inquiry. Such research may also help to inform current debates about the role of induction and mentoring programmes for beginning teachers.

Challenges in the assessment process

The second challenge suggested by data that reveal beginning teachers whose ability to describe good practice lags behind their capacity to enact it, is the way in which a beginning teacher's competence is perceived by those responsible for assessing them and recommending them for permanent teaching contracts. Typically, beginning teachers are assessed by school-based administrators, many of whom rely on multiple measures of beginning teacher competence, including classroom observations and, crucially, interviews and/or informal conversations with other members of staff in the school who may have had opportunity to interact with the beginning teacher. Even when administrators support inquiry-based practices in the classroom, they may be swayed by concerns expressed by other powerful constituents in the educational community, such as parents and experienced senior teachers—particularly if those voices internal to the school (such as senior teachers) indicate that the beginning teacher seems unwilling to collaborate with, or learn from, others. The beginning teacher's capacity to confidently and fluently describe their own vision for teaching, and/or their willingness to 'fit in' with dominant practices in the school, may therefore contribute significantly to how they are perceived in the school community as a competent teacher.

Phronesis is 'knowledge not as a possession…but as invested in action' (Dunne and Pendlebury 2002, p. 198)—specifically ethical action, action oriented to the good—and as Flyvbjerg (2001) notes phronesis concerns itself with addressing three fundamental questions—Where are we going? Is this desirable? What should be done? Daniel showed that he was concerned with whether his practices were desirable—oriented to the good—and was able to take action that showed his knowledge of what ought to be done; yet, he seemed unable to articulate the first dimension of Flyvbjerg's triad: Where are we going? Beginning teachers' responses to explicit or implicit expressions of this dimension in the collective (for example, grade team discussions of team-teaching structures and philosophies) are often seen as a crucial measure of whether they 'fit' in a particular school's vision and structures. In Daniel's case, his inability to articulate how he felt the team's practices should be moving left his team partner at a loss to understand how she might move away from traditional mathematics teaching practices and towards an inquiry orientation. She and Daniel drew away from collaborative teaching (despite a highly conducive physical teaching space they shared) and, as a senior teacher in the building, her opinion of his competence as a beginning teacher no doubt carried weight. Whilst Daniel did gain an ongoing teaching contract with the school board, he moved schools several times in search of a place where inquiry-based teaching practices were widespread amongst the staff. Daniel's case suggests that we still have much to learn about how

inquiry-based practices are fostered and sustained in schools and about how administrators assess beginning teachers who privilege such approaches in their classrooms. Further research on these questions is needed.

Challenges for teacher education practices

From the point of view of preservice teacher education programmes, an immediate response to the aporia identified here might be to effect a fix—to more deliberately teach the language of inquiry to these prospective teachers so that their discourse catches up with their enacted practice. In this way, graduates might put on a better show in employment interviews, and they might also be better able to convince reluctant colleagues in the schools of the value of inquiry-based practice. However, my ongoing research is considering whether directly teaching the talk of inquiry may interrupt the very learning that enables the (embodied) inquiry-based practice to develop (see Smits et al. 2008). Clearly, teaching beginning teachers to talk of (rather than just enact) inquiry in sophisticated ways might be accomplished by more subtle means, and so as a programme we are further developing the avenues through which prospective teachers are able to document their learning so that they have additional and richer opportunities to express what they know. These opportunities include, for example, documenting learning throughout the programme in electronic portfolios and expanding prospective teachers' opportunities to present in public.

As Dunne (1997) in his extensive analysis of phronetic knowledge notes though, 'the knowing person can never quite catch up with how he or she knows…if to be known means to be fully available for inspection and certification by consciousness' (p. 357). Drawing on Gadamer's (1989) work, Dunne (1997) further suggests that phronesis bestows a 'peculiarly intimate kind of self-knowledge without however making this self fully transparent or available' (pp. 126–127) and hence 'the self appears not within the field that can be surveyed by phronesis but rather in the very activity of phronesis itself' (p. 269). Daniel's inability to describe the tenets and practices of inquiry-based learning (despite evidence that he enacts inquiry-based teaching practices in the classroom) emphasises the embodied and tacitly held nature of his knowledge. In addition, Daniel's suggestion that his colleague would need to live through the whole, complexly woven programme of education in which he had participated in order for her to understand his practice reminds us, as teacher educators, that we cannot hope to simply tell learners what inquiry is, that instead they need to *experience* inquiry.

Research has shown that traditional preservice teacher education often has a limited impact on prospective teachers' conceptions of, and relationships with, mathematics and mathematics teaching and on their subsequent professional practice (Ball 1990; Bennett and Jacobs 1998; Ensor 2001). As our teacher preparation programme *does* seem to be having a strong influence on our prospective teachers' relationships with mathematics and on their classroom practices, I am prompted to urge caution in rushing to modify our curriculum, lest we, by focussing attention on the talk of inquiry, disrupt the very embodied practices that we are seeking to foster. Daniel's case suggests that we need to understand more about educating teachers to practice and communicate about inquiry in schools; in other words, to be receptive to the problem rather than to rush to master it with a solution.

Conclusion

Most of the beginning teachers in my study had not experienced inquiry-based mathematics teaching in their own educational histories. Many had come to the programme

feeling very uncomfortable about the prospect of teaching mathematics, though all reported feeling differently by the end of the programme. Several reported that the non-graded nature of the teacher education programme was key in their willingness to undertake an additional mathematics course in their final semester, and that the programme philosophy and structure had enabled them to uncover and face their weaknesses, encouraged them to take on the challenge of addressing the gaps in their preparation, and convinced them of the value of inquiry-based practices. This is heartening information, because inquiry-based materials and classroom practices have been shown to enhance student achievement and/or mathematical understanding as well as attitudes or motivation (see e.g. Boaler 1998; Hickey et al. 2001). There is every reason, then, that teacher educators should continue to encourage such practices through their preservice teacher preparation programmes. The data I have collected show that, given a certain kind of programme philosophy, structure, and activities, beginning teachers, even those like Daniel who enter their programme with limited content area knowledge, can be taught to enact strong inquiry-based practices. However, my data also raise questions about how such programmes might better prepare graduates as they learn to 'talk the talk' of inquiry so that they are better able to articulate their vision for teaching through inquiry and so that their ability to *describe* good practice catches up with their ability to *enact* it.

As I have attempted to show here, strong inquiry-based teaching is nuanced and complex practice and the evidence suggests that for beginning teachers the knowledge upon which such practice rests may be tacitly held, and deeply embodied. As Dunne (2005) notes, against the advantages of control, predictability and accountability offered by a technical approach to teaching, phronetic knowledge—knowledge with an irreducible core of judgment—'can appear makeshift, unreliable, elitist and unaccountable' (p. 377). We might expect that this would leave beginning teachers feeling as though they have no stable ground on which to stand, no confidence in the validity of their approach, and no authority to teach. On the contrary, though, and as Daniel's experience shows, given a programme philosophy, structures, and activities grounded in phronesis, beginning teachers can learn to enact strong inquiry-based practices, even in the face of opposition, or at least lack of understanding, from more experienced teacher-colleagues in the schools.

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