Who Keeps the Gate? Pre-service Teachers' Perceptions on Teaching and Learning Mathematics

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Mathematics has long been known as a gatekeeper: challenging to learn, tricky to successfully access and navigate, and perhaps not even meant for everyone to learn. Pre-service teachers admit to having experienced such gatekeeper characteristics in their own learning of school mathematics. In a study, pre-service teachers were asked questions about their perceptions of teaching and learning mathematics, as well as their perspectives on students' perceptions of learning mathematics. In this paper, responses to these questions are viewed through two different epistemological lenses: one underscores the role of mathematics as a language and the other ponders the role of the teacher in student learning. Both lenses return the discussion to how mathematics is NOT being demystified in school classrooms, but instead is being maintained as gatekeeper.

Introduction

When asked whether mathematics is easier or harder to teach than other subjects, one middle years pre-service teacher responded that it is "not as hard as grammar but harder than social studies." This response, along with other responses that point to the importance of "telling" or "explaining" mathematics so that students 'get it' had us, as researchers, pondering important epistemological questions regarding knowing (in) mathematics. We believe two specific epistemological questions—*what* is being known and *how* it is being known—have a strong influence on student access to, and success in, school mathematics. By examining middle years pre-service teachers' perceptions of teaching and learning mathematics through the lenses created by these two epistemological questions, we believe that we begin to understand the perpetuation of the gatekeeper status of mathematics. In other words, we examine the

epistemological questions: *what* mathematics is being known (underscoring the role of mathematics as language) and *how* is mathematics being known (pondering the role of the teacher in student learning).

The purpose of this paper is to explore the relationship between pre-service teachers' own experiences learning school mathematics and their perceptions on teaching and learning mathematics in middle school (Grades 6-8). The data is drawn from surveys administered to middle years pre-service teachers enrolled in years one through four of a four-year undergraduate teacher education program at a university in a western province of Canada. By reading the survey response data through two different lenses, the paper suggests that the role of teachers in the preservation and maintenance of the gatekeeper status of mathematics cannot go unnoticed, and that there is considerable work to be done in teacher education to dismantle the gate for learners of school mathematics.

What the Literature Says

Some believe that "the birth of mathematics as the privileged discipline or gatekeeper" (Stinson, 2004, p. 9) dates back over 2300 years to the words and writings of Plato. Even though it is assumed that much has changed in society and education since Plato, Volmink (1994) describes mathematics as "an impenetrable mystery to many," clarifying that "in spite of a century of mathematics instruction, most people still feel alienated from the subject" (p. 51). Further, Noyes (2004) confirms that mathematics "has been constructed as the primary gatekeeper ... to future educational and employment opportunities" (p. 278). More subtly, Brown (1997) suggests that even when teachers "encourage students to pursue their own mathematical concerns" as might occur when utilizing non-traditional strategies for teaching mathematics, teachers retain the option of denying students' work as being proper representations of mathematics (p. 1).

Volmink (1994) recommends that there be "a shift from seeing mathematics as involving the 'interpretation of symbolic information' to an emphasis on situating it in the realm of everyday experiences of people" (p. 51). Similarly, Barwell (2008) suggests that students should still "learn to use formal aspects of mathematical discourse" but from a socially discursive position (p. 126). Students' mathematical discourse

and thinking becomes more complex over time through cyclical experiences where "new vocabulary is repeatedly encountered and explored in rich, meaningful contexts" (Barwell, 2008, p. 126). Such a shift in the discourses of seeing mathematics differently would necessarily call for a corresponding shift in discourses on ways of being and acting with mathematics. According to Walshaw (2013), "discourses sketch out, for teachers, ways of being in the classroom ... by systematically constituting specific versions of the social and natural worlds for them, all the while obscuring other possibilities from their vision" (p. 76). In this regard, a gate remains closed. Simply put, maintaining the gatekeeper image of mathematics works to secure specific versions of the world of teaching and learning mathematics, while obscuring other possibilities. However, "a door [or gate] can be open or shut, it depends what you want to do with it (Barton, 2008, p. 61).

Context for Research Study

In the study informing this paper, one author/researcher (Nolan), along with a South African researcher and colleague (Junqueira) sought to study what perceptions individual stakeholders, involved in mathematics teaching and learning, hold for the use of Mathematics Specialist Teachers (MST) in Grades 6-8 (Nolan & Junqueira, 2014). In other words, to study from multiple perspectives the phenomenon of MST and how various educational stakeholders perceive this phenomenon. In the larger study, participants from the five stakeholder groups (school administrators, Grades 6-8 classroom teachers, Grades 6-8 students and their parents, as well as pre-service teachers enrolled in the two universities' teacher education programs) were surveyed. This paper and presentation focuses on one particular stakeholder group— the pre-service teachers being educated to teach mathematics at the middle years level (Grades 6-8) in Canada, and specifically in the western province of Saskatchewan.

In the context of Saskatchewan, the education system consists of Grades K-8 (elementary) schools and Grades 9-12 (secondary) schools. Generally, K-8 schools have generalist teachers (a teacher who is responsible for teaching all subjects at a specific grade level) while 9-12 schools have specialist teachers for each subject area. Recently, discourse around new local curriculum, which has a goal

of teaching for deep understanding using inquiry-based approaches, and the question of who should teach elementary school mathematics circulates among many of the stakeholders named above. In recent research on the role of teacher education in shaping secondary mathematics teacher identity and agency (Nolan, 2014), novice mathematics teachers reported encountering exceptionally limited skills in, and poor attitudes toward, mathematics in students at the Grade 9 level. One of the key recommendations emerging from that study was that schools should have mathematics teaching specialists at the middle years level. Hence, a study was designed to understand what various stakeholders perceived as the potential role of MST in Grades 6-8, and as identified this paper focuses on one such group of stakeholders: middle years pre-service teachers.

Presentation and Discussion of Data

Approximately 85 middle years pre-service teachers were invited to complete an online survey, consisting of two parts. Part A of the survey focused on current attitudes and practices, including questions about pre-service teachers' experiences of learning mathematics and their goals/priorities for teaching it. Part B specifically addressed the concept of the Mathematics Specialist Teacher (MST). Here, questions focused on pre-service teachers' current understanding of, and comfort with, curriculum; whether they would choose to specialize in the teaching of mathematics if that option were available to them, and their ideas on the benefits and shortcomings of the MST. Due to the length and scope of this paper, the questions used for discussion are drawn from Part A; specifically, on pre-service teachers' responses to the three questions:

1. Overall, would you describe your own experience of learning mathematics in school as positive, negative, or somewhat mixed? Please explain.
2. Based on your experience thus far, do you think mathematics will be easier or harder to teach than other subjects? Please explain.
3. Do you think Grade 6-8 students find mathematics easy to learn or hard to learn? Why?

Admittedly, these questions limit responses through their desire to have respondents select from binary or tertiary options. This design was intentional, positioning pre-service teachers to think carefully about if/why they were drawn to one side or another of the dichotomy. The questions were also worded in this manner to be consistent across the different surveys, especially the survey administered to Grade 6-8 students who, we felt, might be more inclined to respond (and explain the response) when presented with an either-or prompt.

As stated earlier, responses to the three survey questions listed above were viewed through two different researcher lenses: one examines the epistemological question of *what* mathematics is being known, underscoring the role of mathematics as language, and the other epistemological question is that of *how* is mathematics being known, pondering the role of the teacher in student learning. The approach taken in this paper is to present reflections on the survey response data when viewed through these two lenses.

What Mathematics is Being Known: The Role of Mathematics as a Language

The idea that mathematics is related to language or that mathematics functions as a language for the communication of mathematical notions is easy to find within the literature. Oldfield (1996) goes so far as to state that "mathematics can be thought of as a language, just like French or Spanish" (p. 22). Brown (1997) writes that "language is instrumental in developing mathematical understanding" (p. 3). Barwell (2008) confirms that "mathematics is commonly seen as a discipline with no place for linguistic ambiguity … [and] perhaps more than in any other discipline, terms are seen as being precisely defined (p. 118). Thus, perhaps it is logical or understandable in teaching and learning school mathematics to focus on teaching linguistic aspects of mathematics such as vocabulary, definitions, the proper use mathematical symbols and the memorization of such mathematical facts.

In looking at the pre-service teachers' data, the word 'explain' occurs among answers to all three of the online survey questions presented above. It appears that the pedagogy of 'explaining' is a hangover from pre-service teachers' own experience learning mathematics. On the

research surveys, pre-service teachers reflect on being students who experienced poor explanations ("I was never taught in a way that I could understand" and "some teachers were not able to explain") and now, as becoming teachers, they reflect on being responsible for producing *better* explanations ("it isn't about explaining again, it is figuring out different ways to explain ideas"; "I do find it difficult to explain things in different ways if students 'don't get it'"; "I think it is harder for me to teach because I want to tell them exactly what to do to get the right answer"). In the minds of these pre-service teachers, explaining occupies a prominent place in teaching and learning mathematics.

In considering the meaning of the word explain, in relation to a linguistic view of mathematics, the data suggests that for some pre-service teachers "mak[ing] (an idea or situation) clear to someone by describing it in more detail or revealing relevant facts" is related, or perhaps most important, to the learning and teaching of mathematics or at least the linguistic aspects of mathematics (http://www.oxforddictionaries.com/definition/english/explain). In unpacking the meaning of 'explain' by continuing with definitions from the Oxford online dictionary, for mathematics to be clear it should be "easy to perceive, understand, or interpret." For mathematics to be easy, it should be "achieved without great effort; presenting few difficulties." If the way to make mathematics clear and easy is to describe mathematics, then one is expected to "give a detailed account in words" of the details (facts). The act of revealing relevant facts implies "making interesting or significant information known, especially of a personal nature" (where a relevant fact is "a thing that is known to be true" and "appropriate to the matter at hand"). In summary, for some students and teachers (including those surveyed), it appears they perceive that learning and teaching mathematics depends upon explanations, easily achievable truths that can simply be revealed if the teacher is knowledgeable.

This formal view of mathematics, reliant upon explanation, is limiting (Barwell, 2008; Renert & Davis, 2010). When only linguistic aspects of mathematics become the focus and when explanation is the preferred method for sharing these aspects, limited mathematical activity becomes stable or traditional in nature. The way mathematics can be 'traditionally taught' might be better understood as the way mathematics is 'normally' taught or learned. For teaching and

learning to be 'normal,' it appears that practices should fall within a more narrow range as represented by any normal curve distribution. Brown (1997) warns that "language functions in orienting action within the normative constraints of a given situation" (p.3). However, in this normally linguistic view of mathematics 'novel' dimensions of mathematical practice including "conceptions of mathematics as emergent, embodied, tacit, enacted and participatory" are constrained and can remain hidden and omitted (Renert & Davis, 2010, p. 196). For at least a decade, some mathematics education researchers have suggested that less focus on 'formal mathematics' is necessary in preparing students for the ever-increasing complexities of society (Alrø and Skovsmose, 2004; Barwell, 2008; Renert & Davis, 2010). For these researchers, the language of mathematics is considered more broadly and more encompassing, inclusive of informal mathematical language, dialogue, participation and cyclical tacit experiences.

In expanding the idea of mathematics as (more than) language, the gate should be able to budge; more students and teachers should be able to participate in discussions about mathematics when mathematics moves beyond memorization of established vocabulary, definitions, symbols, facts and procedures. However, the survey responses from pre-service teachers in this study indicate that for some teachers and students, the narrowed and normally linguistic version of mathematics as language is at least most familiar, if not all that is known. The pre-service teacher survey data reflects the same understanding as that in mathematics education research, namely that "the stable, transcendent conception of mathematics dominate mathematics teaching and learning at the moment" (Renert & Davis, 2010, p. 196).

How is Mathematics Being Known: The Role of the Teacher in Student Learning

When the linguistic version of mathematics is the focus in school mathematics classrooms, mathematics becomes, by and large, less accessible to both teachers and students. Teachers and students begin to perceive the subject of mathematics, along with the teaching and learning of it, as comparable to teaching and learning grammar. In fact, research indicates that students' view of the good mathematics

teacher is one who explains concepts and executes procedures clearly (Murray, 2011; Walls, 2010). A troubling aspect of this grammar metaphor and language lens is that mathematics becomes less about being a human endeavour of problem posing, solving, and reasoning, and more about making sense of (language) rules and procedures, with total dependence on the teacher to provide careful and correct explanations of these rules and procedures. In studying sources of authority in mathematics classrooms, Wagner & Herbel-Eisenmann (2014) found that "[a]uthority was unquestioned and placed in the teacher and in accepted mathematical procedures instead of being a result of justified statements" (p. 202).

The dependence on the teacher for explanation (and corresponding blame for not having explained things properly) was evidenced in the data when, for example, one pre-service teacher stated: "I found some teachers were not able to explain... and so I had to try and teach myself how to do it". Another pre-service teacher alluded to extensive reliance on the teacher in suggesting that "the teacher can make or break a student's learning experience." With responses such as these, it is no wonder that teachers feel personally responsible for student learning. It is as if the linguistic version of mathematics, being the only version of mathematics known, places teachers in a position of authority and responsibility for student learning. It follows then that good teaching, which 'results in' student learning, is all about getting that language across with clear and correct explanations. In other words, the historical persistence and perpetuation of direct teaching (in the form of clear explanations) as the dominant pedagogy presupposes that a 'good explanation' leads to substantive learning.

Educational Significance of Study and Future Directions

Through these two epistemological lenses of *what* is to be known and *how* it is to be known, we have endeavoured to interpret middle years pre-service teachers' responses to questions on the teaching and learning of mathematics, in particular what they view as 'hard' or 'easy' about the processes. Both lenses return the discussion to how mathematics is NOT being demystified in school classrooms, but instead is

being maintained as gatekeeper by teachers' and students' perceptions of what mathematics should be taught and how it should be taught. Access continues to be limited and, even with access, only a limited vision is available for what mathematics is and how it can be known.

In returning to the introduction of this paper, where a middle years pre-service teacher was quoted as saying that mathematics is "not as hard as grammar but harder than social studies" to teach, we reflect on next steps in this research and the implications for teacher education. Firstly, we note that what is needed in working with pre-service teachers is an understanding and recognition that teachers' "own, often troubled relationships with mathematics impact on the ways they interact with learners" (Black, Mendick, & Solomon, 2009, p. 3). More than this, we believe pre-service teachers' understandings of pedagogy, coupled with their understandings of mathematics as a clearly-defined language of rules and procedures, position teachers in a highly regulated environment. Walshaw (2013) proposes that "[t]he teacher's understanding of pedagogy and of the pedagogical relation are both part of a regulatory apparatus, imposing certain meanings that induce that teacher into a particular pedagogical intelligibility" (p. 90). Research drawing on Bourdieu's social field theory (Nolan, 2012) can perhaps help understand the dispositions of new teachers. Using the concept of habitus-field fit, Nolan (2012) draws attention to the highly regulated space where pre-service teachers attempt to negotiate transitions from being students to teachers of mathematics. The analysis points to the realization that mathematics teacher education programs (and, by extension, professional development programs for in-service teachers) are in need of a reconceptualized approach that seeks to disrupt and deconstruct the traditionally performed roles of mathematics teacher and student, while also recognizing the limits of enacting reconceptualized roles within the regulative structures of schools and curriculum.

Asking the question of "[h]ow does a teacher turn herself into a teacher," Walshaw (2013) responds:

> Teachers (as well as others) are not masters of their own thoughts, speech or actions. Their identities are historically and situationally produced by discourses that are often contradictory. The ways in which they teach in the classroom and the ways in which they give meaning to their interactions with students

> are influenced by the discourses made available to them and to the political strength and interest, for the teacher, of those discourses. (p. 80)

With only particular discourses made available to these 'becoming' teachers, in terms of *what* mathematics is being known and *how* it is being known, it is no wonder that pre-service teachers' gaze is limited to envision mere maintenance of the gate to mathematics. The 'explain clearly and correctly' discourse draws teachers to strategies of encouraging their students to believe that they can 'get the right answer' with the proper teacher explanation and student listening disposition. At the same time, teachers and students are expected to accept the reality that mathematics is challenging to learn, tricky to successfully access and navigate, and perhaps not even meant for everyone.

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