PRESERVICE SECONDARY MATHEMATICS TEACHERS’ KNOWLEDGE AND INQUIRY TEACHING APPROACHES

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This paper discusses the nature and role of preservice secondary mathematics teachers’ knowledge that supports their use of inquiry approaches during their practicum teaching. It highlights how four categories of teachers’ knowledge and, more importantly, the connectedness among them based on a common theme influenced the preservice teachers’ use of inquiry approaches and their ability to transform pedagogical theory to practice. The paper also addresses the importance of learning experiences in teacher education that treat these domains of teacher knowledge in an integrated way within classroom-based contextual situations in order to facilitate the development of an appropriate, usable network of knowledge.

This study investigated the nature and role of preservice secondary mathematics teachers’ knowledge that supported their use of inquiry approaches during their practicum teaching. It is part of an ongoing four-year longitudinal study of beginning secondary mathematics teachers’ growth.

RELATED LITERATURE

An inquiry perspective of teaching is considered to be effective to facilitate students’ development of mathematics understanding and mathematics thinking. In inquiry classrooms, students are expected to construct mathematical meaning through reasoning, communicating, exploring, and collaborating with peers and the teacher while working on tasks that are inquiry-oriented activities, including genuine problems and investigations (NCTM, 1991). However, teachers typically find it challenging to adopt inquiry approaches in their teaching, particularly at the secondary level, partly because to teach this way requires teaching differently from how they were taught. Current teacher preparation programs are likely to expose prospective teachers to such approaches to various degrees. However, based on my experience with an inquiry-based program, this exposure, regardless of how substantive, may not result in implementation in the classroom during practicum, even when the supervising teachers give the student teachers the freedom to do so. This raises the issue of when and how are prospective teachers able, or likely, to implement inquiry approaches in their teaching during practicum and potentially in their future practice. This study contributes to our understanding of this issue.

The research literature provides evidence to support concerns about the adequacy of preservice teachers’ knowledge as a basis to teach mathematics in an inquiry way. For example, research studies that examined preservice secondary mathematics teachers’ mathematics knowledge (e.g., Even, 1993; Feiman-Nemser & Remillard, 1996;...
Kinach, 2002; Knuth, 2002) suggest that these teachers often do not hold a sound understanding of the mathematics they need in order to teach it with depth. This includes fundamental concepts from the school curriculum, such as operations with integers, functions, and proof. In contrast to knowledge of mathematics, studies on preservice teachers’ knowledge of mathematics teaching and learning are less represented in the research literature (Ponte & Chapman, 2006). However, some studies show that they could have inadequate understanding of students’ mathematics thinking (Tirosh, 2000; Stacey et al., 2001) and knowledge of communication and questioning (Moyer & Milewicz, 2002; Blanton, Westbrook, & Carter, 2005).

In general, studies on preservice teachers’ knowledge tends to focus on what they do not know than on their sense making (Ponte & Chapman, 2006), including the nature of their knowledge that supports inquiry-oriented teaching. In focusing on their sense making and practical knowledge, this study is framed in a humanistic perspective of teacher thinking in which teachers are viewed as creating their own meaning to make sense of their teaching (Fenstermacher, 1994). It also adopts the perspective of Kilpatrick, Swafford and Findell (2001) that three major components of mathematics teacher knowledge are necessary for effective mathematics teaching: knowledge of mathematics, students, and instructional practices.

**RESEARCH PROCESS**

The study was framed in a qualitative, naturalistic research perspective that focuses on capturing and interpreting peoples’ thinking and actions based on actual settings. Case studies (Stake, 1995) were conducted to allow for in depth examination of the situation. The participants were two secondary preservice mathematics teachers with bachelor degrees in mathematics and were in the second year of their two-year B.Ed. program, which had a focus on inquiry teaching. The study was built around their semester-3 practicum when they were in their assigned schools teaching for most of the semester, four days per week. During this semester, they integrated inquiry approaches in their teaching in spite of being in predominantly traditional classrooms.

The main sources of data were interviews, classroom observations and teaching documents. The open-ended interviews before and after the semester included a focus on: their thinking about mathematics and inquiry teaching and learning; their meanings/interpretations of selected mathematics concepts covered in their teaching; their actual experiences with inquiry approaches during their practicum teaching; their thinking behind planning and conducting their lessons; and their thinking about what supported or inhibited their use of inquiry approaches. Classroom observations were conducted for lessons including and not including inquiry approaches. Data from the observations included teacher-student interactions about the mathematics topics being taught; description of learning activities students engaged in; what the teacher attended to as students worked on mathematics tasks; and teaching strategies for the content. Documents consisted of lesson plans, teacher prepared mathematics activities and field journal records of their reflections on their teaching.
Analysis involved close scrutiny of the data by the researcher and research assistants, focusing on identifying the participants’ knowledge and thinking about mathematics, students’ learning and inquiry teaching; explicit and implicit situations of when, how and why they used inquiry approaches; and apparent relationships between their knowledge or thinking and inquiry teaching. Themes were determined by identifying conceptual factors that characterized each participant’s thinking and practice based on the information from the initial scrutiny of the data. “Pattern” emerged as the most dominant theme in relation to inquiry teaching, then, the data were scrutinized further in order to understand the nature of this theme. Verification procedures included triangulation by comparing outcome from the various data sources, cross checks by research team, member checks and elimination of initial assumptions/themes based on disconfirming evidence.

**FINDINGS**

The two preservice teachers differed in how they planned and conducted their lessons during their practicum teaching, but they exhibited some key similarities that seemed to characterize their sense making of using inquiry approaches. These similarities involved four factors: their beliefs about mathematics, their beliefs about students’ learning, how they held their knowledge of mathematics and their pedagogical knowledge of engaging students in inquiry. In particular, the relationships among these factors seemed to be the key to explaining their use of inquiry approaches. The following highlights the nature of these factors and the relationships among them.

**Beliefs about mathematics:** The participants held a similar core belief about mathematics that provided the foundation for when and how they used inquiry approaches. For Sara, this belief was “patterns, making connections between patterns and the world,” for Reba, “a lot of patterns … can be found everywhere.” They also held the belief in a way that was “central and psychologically strong” (Green, 1971).

**Beliefs about students’ learning:** The participants also held a similar core belief about students’ learning that was compatible with inquiry learning and directly related to the belief about mathematics. This belief focused on having students “make the connections for themselves” (Sara) or “see patterns for themselves” (Reba). As Sara explained, “I always say, can you see a pattern? Like I always said, can you see it? Look for it.” She added, “It was funny because by the end of the class some of the kids would pick up on that and ask, are we looking for patterns again? Yes, we’re always looking for patterns.” The belief also focused on “allowing students to develop their own ideas about things …to find their way to the answer … giving them the space to be able to do that.” (Sara) Similarly, “not that they are discovering everything on their own, but using what knowledge they have, … [then] to be able to make the connections themselves, with each other and being able to ask themselves questions like: does this work? Does this make sense?” (Reba)

**Mathematics knowledge:** The way the participants held their knowledge of mathematics played a significant role in terms of when and how they were able to
transform their beliefs about mathematics and learning into practice. For example, mathematics concepts or procedures that they readily understood, or already held, in terms of patterns were taught through inquiry-oriented approaches. This seemed to be more important than whether they had conceptual versus procedural understanding, since deep understanding of the mathematics was not always present or demonstrated with use of the inquiry approach. The participants were able to associate the concepts and procedures they held as patterns with specific inquiry-learning approaches that focused on the mathematical structure of the concepts or procedures. These approaches involved using a compare/contrast technique with tasks of the form of examples versus non-examples; alternative representation of the same concept; card sorting; concrete situations; and solved examples. Thus, the preservice teachers were able to select or construct tasks that embodied the beliefs about mathematics and learning when they (mathematics, concepts, learning) were all viewed as directly related to pattern as structure or way of knowing. The following are two examples of these mathematical/pedagogical tasks that they created.

Both examples consist of concepts or procedures that were new for the students. Sara’s example: This task dealt with prime and composite numbers in her Grade 7 class. Sara wrote the numbers 1 through 20 on the blackboard. Students were required to work in groups to find the factors of each number based on their prior knowledge. Then, they “must look for patterns found in the factors” and be prepared to share and discuss them in whole-class setting.

Reba’s example: This task dealt with solving systems of linear equation through elimination and substitution as required by the curriculum for her Grade 11 class. Reba prepared three solved examples of elimination and three of substitution. The following is the set of equations used for the elimination cases. A different set was used for substitution.

(i) \[3x - 5y = -9; \quad 4x + 5y = 23\]
(ii) \[2x + 3y - 32 = 0; \quad 3x - 2y - 22 = 0\]
(iii) \[\frac{x - 3}{2} - \frac{y - 5}{3} = 1; \quad \frac{x + 3}{2} + \frac{y - 3}{4} = 1\]

Students were required to “figure out how each process works through the solved examples … [and] to be able to explain fully how and why each method works … how do the examples differ and compare with one another.”[Sara]

The participants’ beliefs about mathematics included connections to the world. But this did not play a significant role in when or how they intentionally used inquiry approaches in teaching a mathematics concept. This aspect of their belief was reflected only in the use of word problems where they tried to include real world-like situations or something to make the task fun in a problem-solving context. Sara did this more often than Reba because the junior high school context she was in seemed to lend itself better to that than the senior high context for Reba. In Sara’s case, a few of the problem solving tasks she used allowed for non-algorithmic skills to arrive at a solution. For
example, she explained, “My key is to make them [the tasks] engaging. … When we did word problems … I had these plastic eggs and I stuck things inside them. … They had to find out what was inside the egg without opening it, and they had to talk about it.” Both participants also, on a few occasions, on introducing a topic provided some historical information about it.

*Instructional knowledge:* Finally, the participants held instructional knowledge for engaging students in the learning tasks that was directly related to their beliefs about learning. In particular, their thinking and practice indicated that this knowledge included use of groups, open/probing questioning, and flexible listening in an inquiry-learning context. For example, Sara explained: “I always tried to make them tell me what they were doing. They would ask a question and I would always try to re-ask the question to them.” She later expanded on this. “[I] say, what do you mean by that? Or where are you going? Or what are you doing with that? So I always tried to listen to their process … how are they thinking and why.” Also, as Reba noted: “I would ask them well what are you thinking of because then that could maybe trigger them without me having to say to them how do you exactly solve this.”

*Practice:* Classroom observations of the preservice teachers’ practice revealed that their inquiry-oriented lessons had a similar structure. Each participant was unique in how this structure was lived in the classroom, but an example from Reba’s case will be used to illustrate the structure, which consisted of the following four stages.

**An introduction stage:** This differed based on the topic and included a check of students’ prior knowledge; brief history of the mathematics concept; and clarifying tasks. For Reba’s Grade 10 introductory lesson on coordinate geometry involving length, midpoint and slope of line segments, she introduced the lesson through a story explaining the history of Descartes and how the coordinate plane was invented. She also clarified the task and explained the unfamiliar notion used for a point.

**An exploration stage:** This involved students’ working on tasks in groups with the teacher posing questions and prompts. For this stage, Reba prepared cards consisting of different representations of the concepts. One set of cards had “length of line segment”, “mid-point of line segment”, and “slope of line segment.” The other sets of cards contained, for each of the three concepts, equations, graphs, problems, and solutions of the problems. Students were required to sort the cards according to the three concepts and be able to explain why their solutions made sense – “how do you know that these go together?” Students first worked in pairs then groups of four to compare and discuss their findings. Reba, in response to their questions, or her observations, would prompt them to think about what they were doing or not noticing.

**A sharing and discussion stage:** Here, students shared and defended their findings in a whole-class setting. Reba guided the discussion to make sure they covered all she expected them to know about the concepts.

**A conclusion stage:** Here, Reba guided the students to think about what they learnt about the concepts and summarized the key ideas.
This brief outline of the lesson does not include the ongoing teacher-student interactions that occurred to facilitate the students’ thinking, inquiry, and sharing processes that were necessary for the lesson to have an inquiry tone.

**DISCUSSION**

The four categories of the preservice teachers’ knowledge described above are key factors in accounting for, and understanding, their use of inquiry approaches in their teaching. But this importance of the four categories of knowledge lies in their interconnectedness. This connectedness provided the two preservice teachers with a logical and viable image of what this teaching could look like. It was necessary for these teachers to transcend other factors, like contextual constraints, in order to teach with inquiry-oriented techniques. In fact, when the interconnectedness was lacking, for example, the mathematics concept was viewed as a fact instead of as a pattern, these teachers resorted to traditional teaching and justified it in terms of the context-ual constraints they perceived, for example, teacher-centered classrooms; limited time; pre-established classroom tone; pre-established sequence of units; nature of topic. As Sara noted: “As a student [teacher], you are living in the partner teachers environment, so this puts constraint on how open-ended I can be in my teaching.”

This integrated view of the preservice teachers’ knowledge could be considered as a network of the preservice teachers’ understandings of key ideas of mathematics, students and instruction and, more importantly, of relationships among them. The following model offers a way of conceptualizing the relationships as held by the preservice teachers. The model connects the preservice teachers’ beliefs and conceptions of mathematics, mathematics concepts and procedures, students and instructional practices when they support inquiry-oriented teaching approaches. In this model, pattern, as it relates to mathematical structure, is the main organizing theme.
that connects mathematics, learner and inquiry pedagogy as follows. First, mathematics as pattern is associated with a mathematics concept/procedure that is viewed in terms of its mathematical structure and, thus, as pattern. Then, this concept or procedure is associated with a mathematical task designed in terms of this pattern. Second, the student is viewed in the role as inquirer in order to learn to think about and see mathematics as pattern. The mathematical task becomes a learning task for the student that involves inquiry of pattern. This learning task is framed in a social context. Third, the teacher is viewed in the role as facilitator in order to support students as inquirers. The mathematical task becomes an instructional task for the teacher that involves using prompts and questioning to help students to notice relevant patterns built into the task.

This model indicates that the preservice teachers constructed an image of inquiry-oriented practice that involved understanding mathematics as patterns, understanding learner as inquirer of patterns and understanding teacher as facilitator of student as inquirer of patterns. As can be expected of novice teachers, these understandings, and thus the image of practice, lacked depth. But, in spite of the quality of their knowledge, whether these understandings were held in a disconnected way or connected way that made sense to them was of more importance in shaping their practice. This connection was important to provide the preservice teachers with an intention of teaching that was explicit and concrete, that is, to help students to see “pattern” as a way of learning and understanding mathematics.

This connectedness, then, was necessary for the preservice teachers to make sense of how to transform their newly constructed theoretical pedagogical knowledge into practical knowledge. In this case, when this connectedness was missing, usually because of lack of association between mathematics as pattern and concept and tasks as pattern, although the teachers still had knowledge about inquiry-oriented pedagogy, there was little evidence of it in their teaching as they resorted to more traditional, teacher-oriented practice. Thus, for preservice teachers such as these participants, the key to developing the connectedness is understanding mathematics as pattern conceptually and pedagogically. This is important for them to be able to select or create mathematical tasks that are relevant and meaningful for investigating patterns and to understand the ways of thinking and roles of the learner and teacher in the inquiry. Thus, to add depth to their practice, they need experiences that will deepen this understanding of mathematics as pattern conceptually and pedagogically. In the context of teacher education, this requires learning experiences that integrate and allow for the integration of knowledge of mathematics, learner and instruction.

CONCLUSION

The findings suggest that preservice secondary teachers could transform theory to practice regarding inquiry teaching if they construct a relevant, integrated view of the three core domains of teacher knowledge – mathematics, instruction and students. This allows them to organize their thinking coherently about what and how they intend to
teach. The findings also suggest that it is important to provide them with experiences that treat these domains of teacher knowledge in an integrated way. Rather than treating the knowledge separately, as is often done in teacher education, an approach that treats them as interwoven within classroom-based situations could help prospective teachers to develop knowledge that is useful and usable.

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**References**


