Learning in and from practice:
Pre-service teachers investigate their mathematics teaching

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Abstract
This study examines the learning of five pre-service teachers as they investigate a question stemming from their practice teaching as part of a final course project in their elementary teacher education program. Analysis of data collected mainly through interviews with pre-service teachers indicate that pre-service teachers developed a relationship with the discipline of mathematics and of teaching mathematics that included the inclination to seek conceptual understanding and pursue a stance of inquiry. This study builds on our understanding of connections between knowledge, practice, and identity and how a teacher education program can offer possibilities for pre-service teachers to negotiate new identities as mathematics teachers who can learn in and from practice.

Introduction
A common challenge for teacher education programmes is to prepare teachers to apply knowledge and understandings learned during university-based classes to problems encountered in real classrooms. University coursework may not reflect the intrinsic complexities and uncertainties of teaching (Clark, 1988). In addition it may oversimplify what occurs in schools, thereby providing an unrepresentative view of teaching (Lieberman, 1995, Lampert & Ball, 1998). School classrooms, on the other hand, are an equally challenging context for teacher educators to make learning teaching educative, rather than as Ball and Cohen (1999) state, reproductive of the kinds of practices familiar to most beginning teachers. Many teacher educators and students would agree with Lampert and Ball's (1998) statement that, “overall teacher education has been a weak intervention on the powerful images, understandings, beliefs, and ways of thinking that prospective teachers bring with them from their prior experiences as students” (p. 24). This raises important questions, then, on how we might design learning environments for future teachers to develop the knowledge, skills, and dispositions that will enable them to be effective in helping students learn mathematics.

One way of addressing this issue is to consider how teaching practice can be a context for learning to teach mathematics. Ball and Cohen (1999) speak about this in terms of learning in and from teaching practice. They argue for a broad view of "in practice" to include not just that which occurs in the classroom but all that is critically necessary in the activity of teaching. This would include, for example, analyzing ways of responding to students' mathematical understandings, designing problems that engage students in mathematical thinking, examining mathematics curriculum materials, or making sense of a student's written solution to a problem. Practice in this sense is not specific to a particular place, nor to physical actions over mental ones, but instead to the explicit and tacit activities that teachers have developed in order to teach (Wenger, 1998). Learning in and from practice, then, requires participation in the activities and discourse of practice. It also requires the use of ideas, understandings, and knowledge in order to
make sense of, learn from, or inquiry into practice. Inquiry into mathematics teaching is an important aspect of learning in and from the practices of teaching and learning. How we might help beginning teachers of mathematics to investigate practice and use what they have learned through coursework to make sense of their teaching is an important area of study.

Research on professional development provided to practicing teachers that focuses on helping teachers learn in and from practice includes opportunities for teachers to examine students’ thinking (Franke, Carpenter, Fennema, 2001; Vacc, Bowman, & Bright, 2000; Clarke et al. ENRP, 2002), reflect on teaching practices (Schifter, 1996), develop or discuss teaching cases (Barnett & Tyson, 1999), or participate in teacher study groups (Stigler and Heibert, 1999). This research show promise toward enhancing teachers’ understanding of mathematics and pedagogy and how they use this knowledge to inform their teaching. However, we know less about how we might support beginning teachers’ to learn in and from practice. Some recent research focuses on introducing new technologies in mathematics teacher education as a resource for inquiry into practice or on integrating field-based experiences into mathematics curriculum and instruction courses (e.g. Ball and Lampert, 1998; Crespo, 2002; Nicol, 1999). Our study builds on this work to examine the learning that occurs when pre-service elementary teachers are given opportunities to investigate their own mathematics teaching practice within a community of learners. This paper examines issues around the kind of instructional resources and structures needed in order to help pre-service teachers develop not only powerful understanding of mathematics and pedagogy, but also a stance of inquiry that will help them use this knowledge to learn in practice. Our findings suggest that opportunities to learn from practice are also opportunities for pre-service teachers to shape identities of themselves as inquiring teachers and to form new identities as learners and teachers of mathematics.

**Theoretical Considerations**

Wenger (1998) provides a social theory of learning within communities of practice that we find useful for our work. A community of practice, according to Wenger, has coherence through the dimensions of mutual engagement and shared activities, a joint enterprise or shared goals, and a shared repertoire of social and physical resources that can be used to meet the negotiated goals. A community of practice could be, for example, the students and teacher of a problem-based elementary school mathematics classroom, or a lecture-based university mathematics methods course, or a group of pre-service teachers teaching in the same school who come together to understand their practice. Wenger argues that learning involves the development of identity, the changing of who we are, in the context of the communities of practice that we participate in. He states: "Because learning transforms who we are and what we can do it is an experience of identity. It is not just an accumulation of skills and information, but a process of becoming—to become a certain person or, conversely, to avoid becoming a certain person" (p. 215). Our identities, then, are shaped and formed by our participation or non-participation in various practices which, in turn, shapes our communities of practice. Identities are more than self-images or narratives of what we think about ourselves, they are, posits Wenger, defined as we interact with others, respond and react to others'
Developing an identity in practice is a constant process of negotiation. "We are always simultaneously dealing with specific situations, participating in the histories of certain practices, and involved in becoming certain persons" (Wenger, 1998, p. 155). The negotiating of identities provides individuals with a vision of who they are or who they imagine themselves to be in relation to a community and its goals, how they belong, and how and why they will participate in the community.

Boaler and Greeno (2000) draw upon the work of Wenger (1998) and of anthropologists Holland, Lachicotte, Skinner, and Cain (1998) to examine how high school students' knowing of mathematics can be understood as participation in particular social practices. In their interviews with students enrolled in discussion-based or more traditional advanced placement calculus courses they found that students' success and participation in mathematics classrooms was based more on their identification with particular practices than their cognitive ability. It was found that students' reflections about their likes or dislikes for the study of mathematics was an "authoring of identities" as learners of mathematics within particular social practices. Some students, for example, were not interested in pursuing mathematics as a field of study because the requirements of the social practices in which they participated as mathematics learners were in conflict with the type of person they wanted to be. That is, these researchers found that different classroom practices encourage students to develop different relationships with the discipline of mathematics that profoundly influence their interest in and learning of mathematics (Boaler, 2002).

Ma's (1999) research is helpful in considering teacher's relationships to the discipline of mathematics. In interviews with experienced elementary school teachers in China, Ma found that these teachers had not only developed understandings of fundamental mathematics that were deep, broad, and thorough but also displayed various mathematical attitudes. Comparing this to American teachers using data collected in Ball's (1990) research, Ma found that Chinese teachers, unlike American teachers sought to "know how to carry out an algorithm and to know why it makes sense mathematically" (Ma, 1999, p. 108). Chinese teachers shared a disposition to ask why and to explore the mathematical reasoning underlying mathematical procedures. They had developed a relationship with the discipline, to use Boaler's (2002) concept, that included the expectation that claims be justified with mathematical arguments and that problems be approached in multiple ways. They saw themselves as participating in a teaching practice that required not only strong procedural and conceptual understandings of mathematics but also the need, ability, and importance of conveying these understandings to students. Chinese teachers developed this relationship through teaching in a community of practice that valued and expected their examining curriculum materials, working with colleagues, learning mathematics from students, and doing mathematics themselves. An important aspect of this research and of Boaler (2002) and Wenger's (1998) is that it brings together learning, practice, and identity. It highlights how social practices, disposition and identity influence what teachers know, how they know it, and how they share their understandings with students. Our research builds on this work as we explore how we might design instructional environments that help beginning teachers develop a
relationship to the discipline of mathematics and to the practices of teaching that enables them to learn in and from practice.

**Research Context and Design**

**The Context**

The context for this study is a 12-month elementary education program for post-baccalaureate students at the University of British Columbia. An option for students in the teacher education program is to enroll in the Problem Based Learning [PBL] cohort. Students in the PBL cohort are placed into small tutorial groups consisting of seven or eight students and their tutor. Following the philosophy of problem based learning, the tutor and students examine various cases of teaching and learning and decide what they need to learn more about in order to understand the issues or problems presented in the case and how they might respond to them. A final assignment for PBL students toward the end of their program is the construction and responding to their own written case of teaching and learning. This study focuses on students of two tutorial groups who were invited to use their teaching practice as a context for their final case project and were provided with opportunities and support to use new technologies as a resource to do this.

**Participants**

Ten of 14 students in two PBL tutorial groups of the 2001-2002 cohort participated in this study. Diversity of the students was representative of teacher education students in Vancouver which included mainly middle class Caucasians and a smaller number of Chinese, Indo-Canadian, and Japanese students of similar economic background. There were nine females and one male ranging in age from their early 20's to mid 30's. During their 13-week extended teaching practicum students met regularly, about every two weeks, as a group to discuss their teaching and the kinds of issues or problems they considered researching as part of their final case project. They were given access to laptop computers and digital cameras so that they could collect and edit video clips of their teaching, interview pupils and teachers, and document student work. During the group meetings students used the technology not only to develop aspects of their final case projects but to also share teaching episodes or pupil's thinking in order to collectively help each other interpret and make sense of teaching practice. After the practicum students were given, as were all students in the PBL cohort, three weeks to produce and respond to a case of teaching and learning. Students had no other program responsibilities at this time. Over this three-week period students met as a group for 3 hours each day where they received and shared their instructional and technical support to create their cases. Five PBL students, all female, in this study created and responded to cases that focused on issues of teaching and learning mathematics. It is the work of these five students that is the focus of this paper.

**Data Collection and Analysis**

Data sources include: video and audio tape recordings of six 90 minute long group meetings held during the practicum; transcripts of individual interviews with students conducted at the end of the practicum as students began extensive work on their case.

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1 Video and audio data were collected only from those pupils whose parents gave consent and only from those teachers who provided consent to participate.
projects and then again at the end of the program as students completed their projects; students' completed cases produced as webpages; and video excerpts collected as students developed their cases. Student case projects were analyzed for the kinds of questions students investigated and how they carried out those investigations. Their reflections on the process of creating their case, were drawn from data collected during the practicum, through the interviews, and from their case projects. These data were analyzed in terms of students' developing ideas about mathematics, how they saw themselves teaching mathematics, the role of inquiry in their teaching, and how each of these developed as they constructed their cases. Using Wenger's (1998) concept of learning as identity transformation in communities of practice, audio and video recordings of group meetings were analyzed to determine the characteristics and nature of discourse of the group meetings and the evolution of students' questions. Data were analyzed using direct interpretation of student responses across the development of their case projects (Stake, 1995).

Results and Discussion

Framing and Investigating a Question

Unlike other students in the PBL cohort who were pursuing the construction of written cases around general pedagogical issues as their final project, PBL students in this study focused their cases around a question or issue that they framed while teaching in the practicum setting. Five pre-service teachers posed questions related to mathematics education. Their questions are: Deb: How can we foster children's growth in numeracy? Jan: How can I develop students' mathematical dispositions? Nat: How can I promote conceptual understanding in mathematics? Tes: How can I use curriculum integration to create learning experiences that will increase my students' conceptual understanding of mathematics? and Nel: How can I improve my students' mathematical communication so that enhanced student learning can occur? These case questions are not questions which framed action research cycles or teacher research projects but are instead broad questions posed by pre-service teachers that stimulated their thinking about how they were and how they might help their students learn mathematics.

In responding to these questions some pre-service teachers used video clips of their teaching and student thinking as a way of interpreting their question. Tes, for example, skeptical for how mathematics might be meaningfully learned through other disciplines, created a short clip of her teaching an "integrated math lesson" and shared this with her peers, teachers, and teacher educators asking for their response to the questions "Is this curriculum integration? and What significant math do you think students' are learning?" Collecting this kind of information, together with an examination of the literature on integration and developing mathematical understanding, Tes was able to conceptualize what curriculum integration could be and how it might look in the mathematics classroom. For many pre-service teachers framing the question was one of the most difficult aspects of the project. Although each had developed a general topic area for research, many found that they were only able to shape a question once their practicum was completed. Jan, for example, found that repeated viewings of her clips helped her define a question. She states: "I was watching my movies so much it really got my mind
going about what the kids were actually saying and what it was that I really wanted to learn more about."

Pre-service teachers' case reports were a collection of video clips and text built as a website with interactive links and opportunities for more public shared discussion. Although there were no required formats given to pre-service teachers in the construction of their case reports, most designed their website beginning with the focus question, often accompanied by a short video clip (about one or two minutes in length) providing contextual information about the nature of the question, the significance of the question for them, general background information on grade level and school in which they were teaching, and a set of sub questions that guided their research. Links were created between the sub questions and other pages providing the viewer with opportunities to explore the questions and the author's analysis through video and text. Some pre-service teachers used video clips to support their text while other used text to support their analysis of video clips.

**Imagining new Possibilities as Learners and Teachers of Math**

Analysis of pre-service teachers' comments collected during group meetings, their reflections contained in the case reports, and interviews conducted as they began their extensive response to their cases indicate that all pre-service teachers were somewhat apprehensive about pursuing a project that focused on mathematics education. All five students stated that they earned good marks in high school mathematics and two stated they were in advanced math groups in elementary and high school. Yet, all said they did not enjoy learning or doing mathematics. Most spoke about their lack of confidence and compared their learning of math to learning in other subject areas in terms of their connection to the discipline. This pre-service teacher's comments are representative of others when she states "My experience in other areas, such as English, was more open-ended [than math], there was room for your opinions and what counted was how you justified them. In math it was either right or wrong, black or white. It was so contrived" (Nel). When asked why they focused their projects in mathematics teaching and learning most stated that they saw it as an opportunity to improve their teaching of math, as this pre-service teacher states, "in order to make it fun and interesting, and not pass on my own math anxieties to my students" (Jan). No pre-service teacher spoke about it as an opportunity to improve her own understanding of math.

Comments made by participants toward the end of their projects and in the final interviews suggest that as they researched their questions they extended their views of themselves as mathematics learners. Most commented that they now recognize not only the importance of their attitude toward math but also the importance of their own understanding of math for teaching. This pre-service teacher, for example, reported that "as a result of my research I've found that in order to promote conceptual understanding it is more than just helping students make connections. It means that I need to have a deeper understanding of math itself so that I can understand what students are saying and doing" (Tes). Through an analysis of student interviews and their teaching, pre-service teachers came to see the need to enrich their own knowledge of math. Nel, for example, states that "it was really through doing and watching all those interviews that I did with
students that I realized if I want to ask students open-ended questions then I need to have a broad range of knowledge and solid math background. Not just knowing how to do things but being able to find the math so that I can ask creative questions." These comments indicate that in the development of their case projects, pre-service teachers found opportunities to extend their understanding of math. Although, only two of the five participants pursued these opportunities in an in-depth way, all spoke about wanting to continue learning more about the math they were expected to teach. What is significant is that pre-service teachers did this in a way that they found exciting and engaging. Their desire to deepen their understanding of math came not with anxiety but with curiosity and commitment to make sense of their students' thinking and provide meaningful tasks that promote student understanding.

As their projects progressed participants also began to consider new possibilities for themselves as mathematics teachers. Many spoke about the importance of conceptual understanding and their interest in helping students communicate their thinking. Tan, for example, interested in helping students "use math to help them understand their world better" explored how she might help students learn math through a study of social issues. "I would like to take an abstract idea like poverty … and have students use mathematics to do a sociological survey of an area. In order to really understand what poverty means it would need all aspects, including mathematics, to make sense of it." Tan, as with others, began to see possibilities for teaching mathematics that they had not seen while in the practicum. Jan, described the project as "life altering, not only for my teaching but for me and for what I view things as." In analyzing and discussing clips of her own and other's teaching she realized that although she thought she was making her lessons "interesting" and "engaging" she was "actually still furthering the notion, of black and white, right and wrong answers." Others, such as Deb, stated that the project "changed my view of teaching. I realize that we really need to know mathematics in order to teach for understanding. And I need to think about it [math] to guide my teaching." Participants spoke about envisioning themselves teaching differently. They explored mathematical connections, issues, and problems they had not considered while they were teaching. Nel, referring to her interviews with students, states, "I learned that I was looking for one answer. It symbolizes a big thing for me because I did that a lot, but that doesn't really allow students to be creative and explore deeper issues." In summarizing her experiences with the project Nel writes: "The project was so amazing because I don't see myself as the same teacher anymore."

**Becoming Inquiring Teachers of Mathematics**

An analysis of the pre-service teachers' discourse during the development of their projects and in the final interviews highlights their increased awareness of the need to make of teaching. Many mentioned that during the practicum they were unable to think deeply about their teaching. They referred to the usefulness of the group meetings where they shared video clips of their teaching, however, as they were teaching they considered these meetings and discussions as "add-ons" to their practice rather than part of their practice. Jan's comments reflect those of others: "During the practicum my mind frame was so focused on planning my lessons and teaching that although I started to get interested in what's going on with these kid's thinking, I saw it at the time as one more
thing to add on." With time after the practicum to analyze their video clips and read the literature many came to value the importance of a deep inquiry into their teaching. Tes, for example, saw her project as an opportunity to "investigate my class and its dynamics on a deeper level." Others spoke further about the value of sharing and analyzing video clips with each other. Tes states "The depth of my project came from my reflective thinking that likely wouldn't have come about had I not seen the movies [her own video clips] with others - the interaction was amazing and helped me see things totally differently." Jan referred to the value of working on the project with others "it made it okay to take a risk and try to learn something new. You knew you weren't alone. That's why it was nice to have that community of people working on something together." They mentioned the importance, for them, of being able to choose their own question to investigate and all pre-service teachers spoke about how much work and effort they put into their projects as well as how it consummed their thinking. Jan for example spoke about how she carried a small notebook around with her "because I'd be thinking about it all the time and I could just jot down little notes if I was at the beach, on the bus, or driving at a stop light. It was really neat because it just totally occupied my thoughts." For some it was not after the project was complete that they realized the importance of making such inquiry into teaching a part of daily teaching practices. Pre-service teachers' commitment to a stance of inquiry is evident in their comments when many stated that, although the project was complete, they were still committed to pursuing questions (e.g. the relationship between mathematical disposition and gender or the nature of mathematics curriculum that fosters narrow thinking) that they did not have a chance to address in their case projects.

Conclusion
The results of this study provide insight into the development of pre-service teachers' learning about mathematics, pedagogy, and inquiry. Studies of experienced and prospective teachers' subject-matter knowledge indicate that teachers require a rich and connected understanding of the mathematics they will be teaching in order to teach well. Ma's (1999) research suggests that teachers can develop their understanding of mathematics for teaching over their teaching careers as well as develop productive attitudes, such as an inclination to pursue conceptual understanding of a concept, seek alternative solutions to problems, and require mathematical reasoning to justify. All students in our study spoke about their interest in developing their own understanding of mathematics and the need for this in order to better understand and hear their students' thinking as well as create meaningful problems for their students to explore. The results indicate that with an investigation of their own teaching pre-service teachers came to develop a different relationship to the discipline of mathematics. Rather than seeing mathematics as uninteresting and disconnected it became a place of curiosity and intrigue as they sought to make sense of their students' mathematical work. They began to reclaim their interest and confidence in learning mathematics. Their identities of themselves as learners of mathematics were being shaped to include the desire to make sense of mathematics, pursue multiple solutions to problems, and make connections within and beyond the discipline. This was intricately tied to their images of themselves as mathematics teachers. Pre-service teachers recognized that with a deeper understanding of mathematics they were able to see possibilities for teaching
mathematics that had previously gone unnoticed. In addition, all spoke about the value of their projects in helping them think critically about their teaching. Although pre-service teachers discussed how their case projects profoundly changed their views of mathematics, teaching mathematics, and what is involved in making sense of teaching, how they use these new understandings and attitudes in their practice as beginning teachers is an area for further research. That is, how these identities as learners and teachers of mathematics continue to be negotiated as these teachers participate in the culture of schools is an important question.

We should also state that this is a small study of five pre-service teachers who chose to investigate an issue related to mathematics teaching. These pre-service teachers were likely ready to, as Jan, said "take the risk" and study an area that was not their strength or first interest. This raises questions on how we might provide opportunities to engage other students who may not be as ready or willing to take this risk. Participants in this study were also unique in that the tools offered as resources for their learning were different from those offered to other teacher education students. Students participating in this study had opportunities to form a community of practice that valued the investigation of teaching. They sought each other's ideas and suggestions in their attempts to make sense of their teaching. They engaged in discussion, debate, and pursued different points of view as they shared clips of their teaching with each other. Certainly access to new technologies as resources for their learning was a factor shaping this community of inquiry. Collecting digital video clips, editing these, and making short movies to share with others structured the kinds of discourse and inquiry questions pursued by participants. Three of the five pre-service teachers spoke about how different their work on this project was from their previous teacher education experiences. Although they were in a problem-based learning cohort that encouraged individual and collective research, they did not consider this as an opportunity for in-depth critical reflection. Nor was the practicum a place for such learning. Instead, pre-service teachers found they were best able to learn in and from practice with opportunities to collect evidence or artifacts of their teaching and with time afforded them after the practicum to discuss and research issues related to these.

This study shows that pre-service teacher education can have a profound influence on students' understanding of mathematics and pedagogy as well as their inclinations to learn mathematics and study mathematics teaching. This study provides insight into the possibilities of providing pre-service teachers with support and time to participate in a community of inquiry, to negotiate identities as inquiring teachers, and to include inquiry in their lives as teachers. Building on Boaler's (2002) work and Ma's (1999) research, this study emphasizes the interconnectedness of knowledge, practice, and identity, and points to the possibilities teacher education can offer in helping pre-service teachers develop a relationship to the discipline of mathematics and of teaching mathematics that involves learning in and from practice.