

DEVELOPING MATHEMATICAL KNOWLEDGE FOR TEACHING THROUGH MENTOR-GUIDED LESSON STUDY

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Field experience can be a rich site for prospective teachers to develop the knowledge and skills they need for effective teaching, however little is known about how structures for supporting interactions between mentor and prospective teachers can maximize prospective teachers' learning. Lesson study has been shown to enhance practicing teachers' mathematical knowledge for teaching through collaborative inquiry with their peers. In this paper, we discuss the use of mentor-guided lesson study to support mentor and prospective teachers' collaboration in the field and provide evidence showing its potential to strengthen prospective teachers' mathematical knowledge for teaching. We will also share insights from the field for those interested in implementing this activity in teacher preparation coursework.

Keywords: Teacher Preparation, Mathematical Knowledge for Teaching, Lesson Study, Secondary Mathematics

Background

The apprenticeship structure known as “student teaching,” “field experience,” or “internship” is a universal part of teacher preparation, in both traditional and alternative certification pathways. Teachers often cite the field experience as the most valuable part of teacher preparation (Lortie, 1975). Over 1,400 institutions of higher education require completion of a student teaching experience for teacher candidates and 39 states in the U.S. have set minimum requirements for the length of the student teaching experience (NCTQ, 2011). Given the importance of field experience in teacher preparation, it is surprising that research on what prospective teachers learn in the field, as well as aspects that promote productive relationships between mentor and novice teachers, is so scarce (Wilson, Floden & Ferrini-Mundy, 2001). Existing research has predominately investigated how field experiences influence novice teachers' beliefs about teaching, but more research is needed to learn about *what* knowledge and skills novice teachers are learning through field experiences.

One type of knowledge that field experiences may provide rich opportunities for prospective teachers to develop is *mathematical knowledge for teaching* (Ball & Bass, 2003). Ball, Thames and Phelps (2008) define MKT as the “mathematical knowledge needed to perform the recurrent tasks of teaching mathematics to students” (p. 399). Over the past decade, much attention has been placed on the role of MKT in understanding the knowledge, skills, and dispositions needed for mathematics teachers to engage in ambitious practice. Lampert and Graziani (2009) define ambitious practice as mathematics instruction that provides all students with an opportunity to develop multifaceted knowledge of mathematics, participate in discussions about mathematical ideas, and solve authentic problems. Prospective teachers need opportunities to develop and deepen MKT if they are to enact ambitious practice.

For prospective secondary teachers of mathematics (PST-Ms), the mathematics coursework required as part of a teacher certification program can offer opportunities to deepen subject matter knowledge. However, these content courses are not designed to develop other aspects of MKT, such as *knowledge of content and teaching* (KCT), which Hill et al. (2008) describe as the

knowledge needed to select an appropriate representation to highlight key concepts in a mathematical investigation or choosing effective instructional examples. Opportunities to develop aspects of MKT such as KCT and KCS (*knowledge of content and students*) may occur in mathematics pedagogy coursework and in field experiences. One experience that has been shown to promote teachers' MKT is lesson study, a particular form of collaborative action research (Fernandez, 2005). The purpose of this paper is to share findings from an investigation into the potential for *mentor-guided lesson study*, where a mentor teacher collaborates with PST-Ms to do lesson study cycles, to support growth in PST-Ms' MKT. Specifically, we will discuss findings to address the following questions: *To what extent does mentor-guided lesson study promote prospective teachers' reflections on teaching related to their MKT? How does a mentor's prior experience in doing lesson study contribute to the development of prospective teachers' MKT during cycles of mentor-guided lesson study?*

Theoretical Framework

Mentor-guided lesson study (MGLS) is an abbreviated form of lesson study that involves a small team consisting of a mentor teacher and two or more PST-Ms collaborating during four phases of a lesson study cycle: 1) develop a learning goal within the context of a unit of instruction; 2) design a lesson that addresses that learning goal; 3) collect evidence of student thinking related to the goal when the lesson is taught, and; 4) discuss the effectiveness of the lesson in achieving the desired learning goal after the lesson. A wealth of research shows how lesson study as professional development contributes to the development of teachers' PCK and MKT (see Fernandez & Yoshida, 2004; Lewis, 2005), and that focusing on specific events and teaching situations is a feature of effective mentoring practice (Wang & Odell, 2002). For PST-Ms, we posit that MGLS offers rich experiences in examining student thinking and linking evidence of student learning to specific instructional decisions, both planned and spontaneous.

One aim of this study was to investigate to what extent MGLS promoted novice teachers to reflect on teaching practice in ways that would develop their MKT. The MKT framework (Hill, Ball & Schilling, 2008) provides a foundation for examining the knowledge used in the work of teaching mathematics, which has been largely achieved to this point by analyzing responses to carefully designed written assessments (e.g. Hill, Schilling, & Ball, 2004). This research shows that the MKT framework is well suited to categorize the actions PST-Ms might make in a classroom setting. In the current study, however, we are focused on PST-Ms' observations of practice, instead of their actions in response to particular tasks. The work of Sherin and Van Es (2005) explores how teachers learn to *notice*, both attending to particular events in an instructional setting and making sense of those events. Building upon this work, we examined the relation between the aspects of instructional practice to the PST-Ms noticed and reflected upon, and their developing knowledge of mathematics and of teaching. Given that the MGLS experience provided the PST-Ms opportunities to plan, enact and reflect on instruction with real students and within the context of a real curriculum, we anticipated the experience might allow them access to particular subdomains of the MKT framework, specifically *knowledge of content and students* (KCS), and *knowledge of content and teaching* (KCT). The PST-Ms would only gain access to this knowledge, however, if they attended to the features of instruction that pertained to those knowledge domains.

Using a grounded theory approach, we constructed a mapping to particular domains of MKT. Our resultant analytic framework, Figure 1, represents the relation between observations made by PST-Ms and their corresponding MKT subdomains. In this framework, PST-Ms' observations *analyzing mathematics* suggest opportunities to develop MKT of specialized content knowledge.

Likewise, PST-M's work *attending to student thinking* corresponds to their MKT domain knowledge of content and students. Finally, PST-Ms work *analyzing teaching moves* provides evidence of their MKT within the knowledge of content and teaching domain.

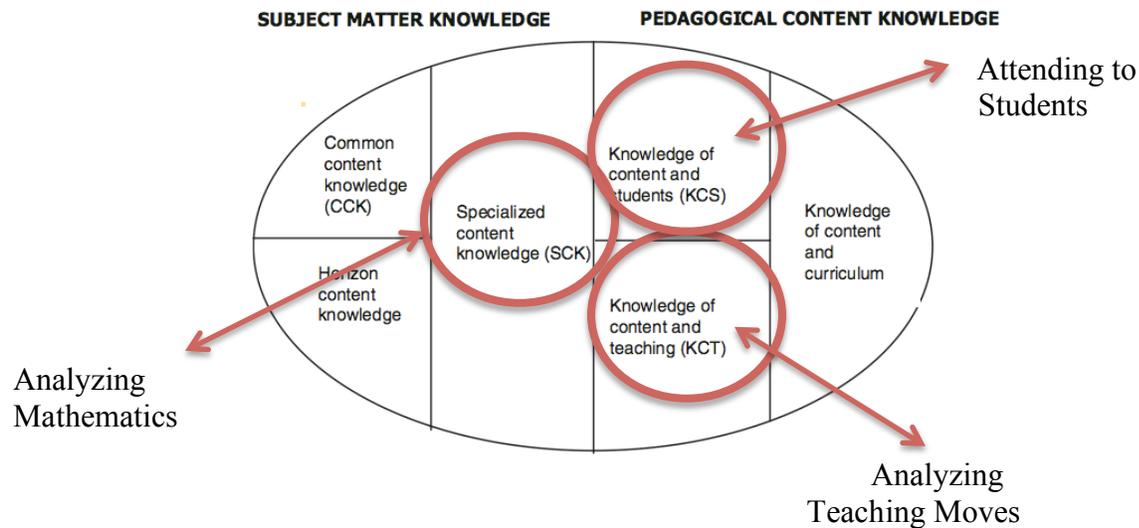


Figure 1: Mapping PST-Ms' Observations to their MKT

Each of the three categories represented in Figure 1, is comprised of a set of subcategories of observations or analyses made by the intern teachers in this study. The descriptions below briefly describe the three overarching categories, with subcategories listed in Figure 2.

Analyzing Mathematics	Attending to Student Thinking	Analyzing Teaching Moves
Analyzing mathematics related to: <ul style="list-style-type: none"> students' thinking teaching moves 	Observations of: <ul style="list-style-type: none"> students' misconceptions student understanding mathematical procedures students' prior knowledge student engagement student discourse students' ability to apply new knowledge Questioning/wondering about student thinking	Analyzing teaching moves related to: <ul style="list-style-type: none"> students' misconceptions students' prior knowledge. students' thinking students' mathematical procedures students' discourse students' engagement

Figure 2. Composition of Categories

Analyzing Mathematics

Statements in this category focus on the mathematics of a particular lesson, perhaps reflecting upon the mathematical features of students' verbal or written responses or attending to the mathematics of teaching moves. We did not include observations regarding the pedagogical features of the lesson included in this category. Due to our primary focus on the mathematical

content, we interpreted that observations that analyze mathematics may relate to development of PST-Ms' SCK. One example of a response coded as *analyzing mathematics of students' thinking* is: "Students discussed all but one possible method to estimate the area." Here, the PST-M specifically analyzes the mathematics content, not the students interaction or instruction.

Attending to Students' Thinking

This category includes observations pertaining to students' thinking, procedures or interactions. This includes observations of how students made sense of the mathematical concepts, misconceptions, or how students interact with one another or with the teacher. This category also includes the PST-Ms' questions or hypothetical wondering about students' thinking. Within the subcategories of this code, we also made the distinction between a focus on students' understanding of concepts and students' ability to execute procedures, as well as discussion of students' prior knowledge and how students might use the knowledge they acquired from the target lesson in the future. For example, the response "Students were having trouble determining the effect of the negative leading coefficient on the shape of the graph" was coded to *observations of students' misconceptions*.

Analyzing Teaching Moves

This category captures PST-Ms' statements related to their teaching moves or the observations of the teaching moves of their partner or mentor teacher. Such observations include analysis of the reasoning for a particular teaching move. The subcategories group the intern teachers' observations based on what they interpreted to motivation of the teaching move to be. For instance, responses coded to the category *analyzing teaching moves related to students' discourse* were similar to the following: "Putting the students in small groups helped them be able to share lots of ideas together." We interpreted this as the PST-M remarking on the impact on classroom discourse of the team's instructional decision to use small groups.

Methods

The setting for this study was a second course of a four-course sequence of mathematics pedagogy courses taken by undergraduate prospective secondary mathematics teachers at a large, Midwestern university. The first two courses in the sequence are typically completed during the senior year of a Bachelor's degree program and prior to full-time student teaching placement.

Participants in this study (n=17) were enrolled in the second mathematics pedagogy course, which we will call Methods II. In Methods II, students participate in: 1) a seminar component for three hours per week; 2) a lab component where students learn methods of teaching in their minor area, as well as issues related to working with students with special needs; and 3) a field placement component (4 hours per week in a middle or high school mathematics class). Two of the stated aims of the course were to explore issues entailed with enacting high cognitive demand tasks (such as issues of equity, social justice, discourse techniques, and complex instruction), and to develop prospective teachers' mathematical knowledge for teaching geometry. The mentor-guided lesson study assignment in this course was intended to maximize students' experiences in learning from their mentor teacher during the field placement component.

Mentor-guided lesson study

The mentor-guided lesson study activity consists of four phases, completed as a cycle, with two cycles during the semester. The team met first to set goals for the lesson study, and the PST-

Ms were required to completed an online Goals Development Log, answering questions such as “Write the content goal you have for this lesson” and “Indicate any questions or concerns you have at this point about the goals you have developed for this lesson study.” The Goals Development Log was submitted prior to the next phase, and reviewed by the course instructor. The process of this first phase was the same during Cycle 2.

In the second phase, *planning*, the team met to design the lesson plan to address the chosen goals, as well as discuss how the team members who would not be teaching would observe the lesson and document students’ thinking during the lesson. Because of the PST-Ms’ limited teaching experience, especially with regards to planning and enacting lessons, the mentor teacher in each team was the lead teacher for Cycle 1. The novice teachers met and discussed possibilities for the lesson with the mentor teacher, however, the mentor teacher took primary responsibility for final decisions regarding the lesson plan for the first cycle. In Cycle 2, the novice teachers enacted the role of lead teachers for the study lesson, to provide a structure for scaffolded experience in leading lessons for an entire class period. Participants completed two online logs for planning: 1) thinking about the mathematical content of their lesson (Topic Study Log) and 2) planning for data collection and observation (Observation Guide Log). In addition to responding to these logs, novice teachers submitted a completed lesson plan to the Methods II course instructor (first author) in advance of teaching the lesson.

In phase 3, *Teaching*, the members of the lesson study team observed the study lesson taught by the lead teacher. In Cycle 1, the novice teachers observed the mentor teacher teach the study lesson, whereas in Cycle 2 the novice teachers taught the lesson while the mentor teacher and, in some cases other interns, observed. In the fourth, and final, phase, *the Post-Lesson Discussion*, teams reflected upon the lesson enactment and considered possible revisions to make to the lesson to better achieve the desired learning goals. Prior to meeting as a team to discuss the lesson, and no more than 24 hours after the lesson enactment, the PST-Ms completed an online Lesson Reflection Log. After teams met to discuss the lesson enactment, the PST-Ms completed a final online log, the Post-Lesson Reflection Log. In this log, PST-Ms reported on the revisions the team decided to make to the study lesson, if any, as well as reflected upon the process of collaborating with their team. Participants also submitted a revised lesson plan and reflection paper at the end of the cycle. The process of completing phase 4 was consistent across cycles. The Lesson Reflection and Post-Lesson Discussion Logs consisted of questions such as:

“List one or two observations you would like to share with the team. Be as specific as possible about the evidence of student thinking that you observed.” (Lesson Reflection)

“Discuss how your team came to make decisions about the revisions. You will want to discuss what seemed to be the most important pieces of evidence collected about what students learned.” (Post-Lesson Discussion)

Method of Analysis

To examine the opportunities the PST-Ms had to develop their knowledge and skills for teaching, we first examined the video conversations and written logs for two focus teams. These teams were chosen for our initial examination because the PST-Ms reported their lesson study experiences to be quite distinct from one another. This close investigation of the all of written and video data for the two focus teams revealed that the Lesson Reflection Log and Post-Lesson Discussion Logs contained significant evidence of the intern teachers’ opportunities to develop their MKT and would serve as the primary source of data for this investigation.

We used a modified grounded theory (Strauss & Corbin, 1976) approach to analyze the written logs. We identified instances in which the intern teachers' noticed particular features of the lesson related to their knowledge of mathematics, students and of teaching. The unit of analysis for this examination was the individual, as each intern teacher had opportunities to develop their knowledge independently from their team members. After the initial open coding, we generated codes for the emergent themes. The PST-Ms responses fell into three general categories: (a) analyzing the mathematics of the lesson, (b) attending to students' thinking, (c) analyzing teaching moves. Using these categories, we developed the coding scheme shown in Figure 2. The category definitions were refined through a constant comparative method. We later mapped the refined categories onto to the domains of MKT, represented in Figure 1.

Results

We coded 340 instances of reflection related to MKT (see Fig. 2) in participants' responses to the lesson reflection and post-lesson discussion logs across both Cycle 1 and Cycle 2. Figure 3 shows the results across three categories of observation. A couple of results worth noting in Figure 3 are that there were more instances of codes related to attending to student thinking than the other two categories, and there were more codes overall in Cycle 2 than in Cycle 1. Although the mean number of instances of attending to student thinking coded was greater in Cycle 2 than in Cycle 1, this difference is statistically insignificant ($p = 0.162$).

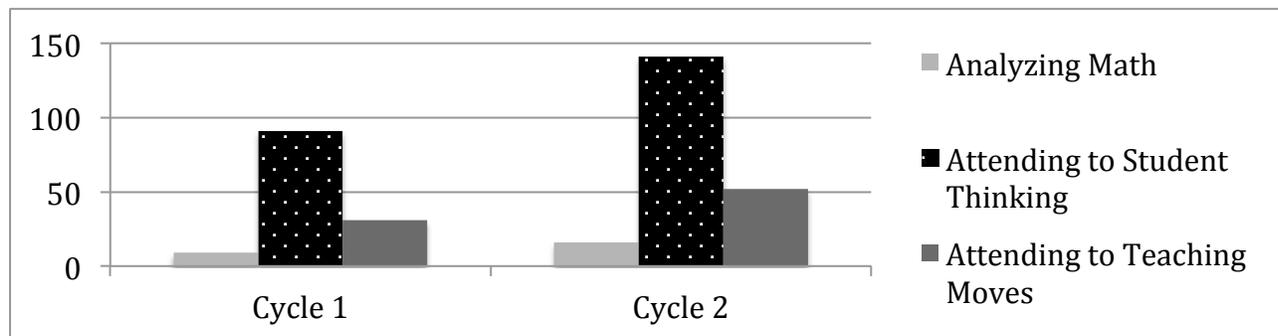


Figure 3: Frequency of MKT codes by cycle

There are at least a few possible reasons for the increase in responses coded into one of the 3 general categories of reflection that develops MKT from Cycle 1 to Cycle 2. First, the prospective teachers may have become more familiar with the prompts and the process of lesson study and could focus more on lesson study process and learning from the lesson observation instead of the mechanics of completing a lesson study cycle. Another possible reason for the difference is the shift in the prospective teachers' role in the lesson study process from Cycle 1 to Cycle 2. The prospective teachers' assumed the role of the study lesson teacher in Cycle 2, and that role may have afforded opportunities to recognize important moments in the lesson related to student thinking that are not as apparent when in the observer role.

Figure 4 provides a breakdown of the kinds of reflections about students' thinking that surfaced in the responses across both the Lesson Reflection and Post-Lesson Discussion Logs. The data in Figure 4 suggest that PST-Ms were more likely to notice aspects of students' engagement in the lesson. The data also indicate that PST-Ms' responses that discussed students' thinking related to mathematical procedures were relatively low compared to other categories (such as reflections on students' understanding).

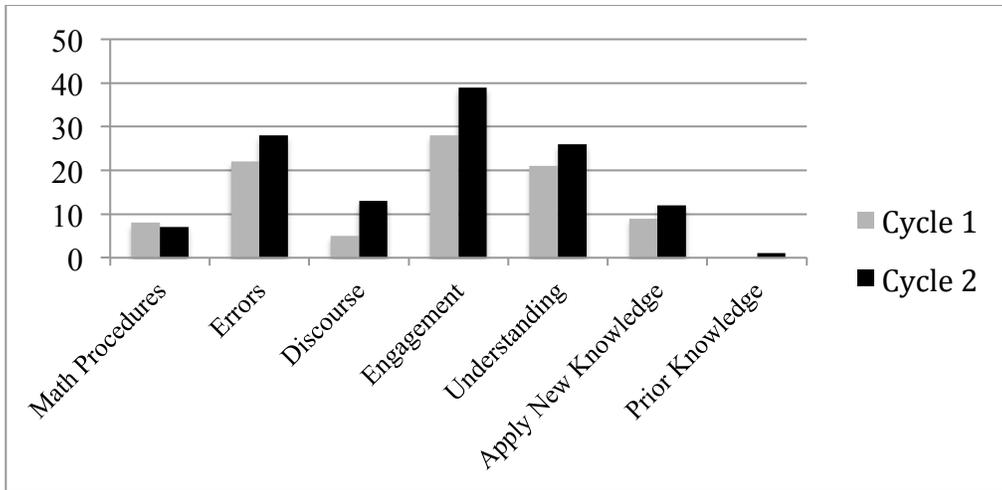


Figure 4: Sub-Codes Assigned for Responses Attending to Students' Thinking

One initial hypothesis of the study was that the more familiar a mentor teacher was with the lesson study process, especially when they have completed lesson study with other colleagues as a part of their professional development, the more frequently prospective teachers would reflect upon the lesson in ways that could develop their MKT. Figure 5 shows the frequency of codes assigned to the three categories of observation with respect to mentor's lesson study experience.

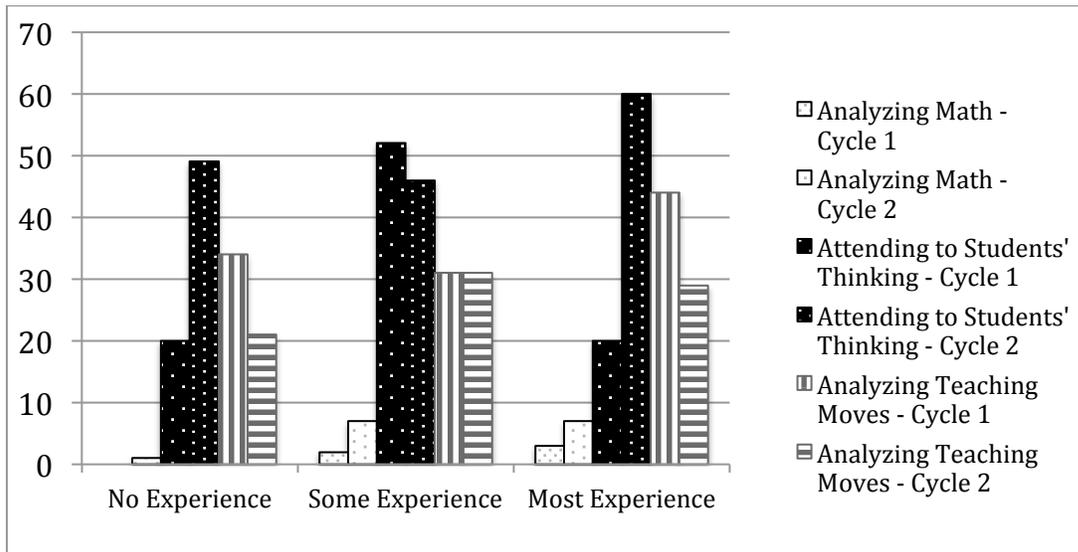


Figure 5: Frequency of MKT codes disaggregated by mentors' lesson study experience

As can be seen in Fig. 5, more mentor teacher experience with lesson study correlates with greater frequency in codes assigned to prospective teachers' responses to the lesson reflection and post-lesson discussion logs, and level of experience is a significant predictor of increased frequency in responses coded to the three categories of observation ($F(2,13) = 4.515, p = 0.032$). The results also show the significant increase in responses coded for attending to students' thinking in Cycle 2, especially for PST-Ms whose mentors had the most lesson study experience.

Discussion

Although the analyses are ongoing, these results suggest that the mentor-guided lesson study experience focuses PST-Ms' attention upon student thinking during study lessons and, thus, may support the development of one particular aspects of MKT known as *knowledge of content and students* (KCS). The results also suggest that PST-Ms' capacity for noticing aspects of instruction related to students' thinking and key teaching moves improves with more experience in doing mentor-guided lesson study. Although significant differences were found in the frequency of MKT codes assigned to responses from PST-Ms to the writing prompts in the logs when aggregated by mentors' experience, we are conducting ongoing analyses to investigate how mentors' experience might be shaping PST-Ms' reflections during the lesson study process. Preliminary findings suggest that mentors' experience with lesson study supports their capacity to facilitate procedures during the lesson study process, but a more critical factor may be how mentors position PST-Ms as collaborators during Cycle 1. We are discovering that mentors who invite PST-Ms to be collaborators in designing the lesson during Cycle 1, when the mentor takes responsibility for teaching the lesson, establishes norms for future lesson study cycles that engage PST-Ms in more thoughtful reflection.

Acknowledgements

This study was funded by an MSU Lilly Fellowship awarded to the first author.

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