LESSON STUDY AS A LEARNING ENVIRONMENT FOR MATHEMATICS COACHES

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This qualitative study focused on the development of three mathematics coaches as they engaged in the lesson study process over the course of two school years. The coaches progressively designed, taught, and refined standards-based lessons which they co-taught with classroom teachers. Coaches developed mathematical knowledge for teaching in three ways. First, they developed knowledge of content and teaching by entering into cognitive dissonance with teachers and collaborating with them to place a stronger emphasis on inquiry in lessons. In addition, they developed knowledge of content and students as they listened to students and observed them on videotape. Finally, they developed specialized content knowledge by considering mathematical perturbations from the lesson with the teacher.

BACKGROUND AND RELATED LITERATURE

The field of professional development coaching currently enjoys steady growth in mathematics education as schools are searching for effective ways to support the learning of in-service teachers (National Council of Teachers of Mathematics, 2000; Stigler & Hiebert, 1999). Although coaching is gaining popularity as a means of professional development, its forms of implementation vary from context to context (Olson & Barrett, 2004). Not only do the requirements to become a coach vary widely but also the professional development afforded to coaches. Finally, research on the professional development of coaches is sketchy at best.

The National Science Foundation (NSF) has established a program that provides coaches for schools: Graduate Fellows in K-12 Education (GK-12). The purpose of this study was to examine the professional development of coaches, or Fellows, within the context of GK-12. Nationwide, the GK-12 program awards grants to universities to place graduate students from disciplines of science, technology, engineering, and mathematics (STEM) into K-12 classrooms for the purpose of jointly designing and delivering K-12 science and mathematics instruction with classroom teachers. Consequently, the GK-12 program integrates research and

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teaching through a professional development model (Moore, 2003) which is a form of *collaborative coaching* (Olson & Barrett, 2004).

Although Fellows are not necessarily mathematics and science education majors, they are hired based on their stated openness towards inquiry-based instruction. Moreover, training of Fellows in constructivism and pedagogy consistent with established mathematics and science standards is expected to occur on campus (NSF, 2004). Thus, this study sought to examine the professional development of the Fellows as they engaged in lesson study as a form of professional development.

Lesson study has captured the attention of professional developers in the United States as they attempt to provide learning environments for teachers which impact student understanding (Stigler & Hiebert, 1999). Originating in Japan, lesson study involves a cyclical process of researching, developing or adapting, teaching and observing, revising, and repeating lessons. In Japan, lesson study has steadily and positively impacted teachers to change from teacher-directed to student directed instruction (Takahashi & Yoshida, 2004). In their influential book, *The Teaching Gap*, Stigler and Hiebert (1999), made a case for radical change in the professional development of American teachers through lesson study. Since that time, lesson study in the United States has spread rapidly and taken numerous forms as schools seek to capture its essential elements in their particular contexts (Fernandez, 2005; Lewis et al., 2006).

As various educational stakeholders have implemented lesson study, promising yet limited results regarding teacher development have emerged. For example, Fernandez (2005) found lesson study to provide elementary teachers opportunities to develop new pedagogical content knowledge, to learn how to reason mathematically, and gave them the incentive to learn more mathematics. Presmeg and Barrett (2003) likewise found that lesson study encouraged teachers to anticipate students' reasoning and strategies related to mathematical concepts. Finally, Pothen and Murata (2007) found lesson study to support the development and transformation of teachers' content knowledge, pedagogical knowledge, and pedagogical content knowledge.

Given our emerging knowledge about the benefits of lesson study for professional development, we decided to employ lesson study in the professional development of the GK-12 coaches at Mid Western University (pseudonym). Thus, we ask:

> In what ways do collaborative coaches develop as they engage in lesson study? In particular in this environment, in what ways do mathematics teachers and coaches develop mathematical knowledge for teaching?

The focus of this paper is on the development of the collaborative coaches.

THEORETICAL FRAMEWORK

During the course of a developmental research project, Cobb & Yackel (2004) found a need for a framework that coordinated the psychological and social perspectives. The emergent perspective, described as being a version of social constructivism which coordinated interactionism and psychological constructivism, came from finding neither the social aspects of learning nor the individual psychological aspects were elevated above the other but rather are "reflexively related such that neither exists independently of the other" (p. 212). Thus the emergent perspective was developed to be a joint perspective in which social norms develop alongside and are constrained by the reorganization of beliefs. The emergent perspective appeared especially suited to this study because the construct of mathematical knowledge for teaching (MKT), on which our analysis is based, is inextricably related to the construct of classroom social norms as outlined in the emergent perspective (Ball, 2003; Cobb & Yackel, 2004). Thus, we chose the emergent perspective as a theoretical framework to study teacher development of mathematical knowledge for teaching.

We chose to analyse our data using the theory of mathematical knowledge for teaching (**MKT**) because of its link to student achievement. The seminal study relating teacher knowledge to student achievement found that MKT was a key to predicting student gains in first and third grade (Hill, Rowan, & Ball, 2004). Ball, Bass, Goffney, and Sleep (2006) defined MKT as the "mathematical knowledge, skills, [and] habits of mind that are entailed by the work of teaching" (p. 5). More specifically, MKT is categorized in six parts (See Table 1). Common content knowledge is basic (**CCK**), lay-person knowledge of the mathematical content. Specialized content knowledge (**SCK**) is the way the mathematics arises in classrooms, such as for building representations. Knowledge of content and students (**KCS**) is knowing how students think about mathematics. Knowledge of content and teaching (**KCT**) involves knowing the most effective examples or teaching sequences. We understand Shulman's (1987) definition of pedagogical content knowledge to be a marriage of KCS with KCT. Knowledge of curriculum and knowledge at the mathematical horizon are the final components of mathematical knowledge for teaching. In this study, we focused on SCK, KCS, and KCT.

Subject Matter Knowledge	**Pedagogical Content Knowledge**
Common Content Knowledge (CCK)	Knowledge of Content and Students (KCS)
Specialized Content Knowledge (SCK)	Knowledge of Content and Teaching (KCT)
Knowledge at the Mathematical Horizon	Knowledge of Curriculum

Table 1: Mathematical Knowledge for Teaching.

METHODS OF DATA COLLECTION AND ANALYSIS

We chose to employ qualitative, multi-tiered teacher development experiment (TDE) methodology because the goal of a TDE is to generate models for teachers' mathematical and pedagogical development, closely matching our research aims for the collaborative coaches (Lesh & Kelly, 2000; Presmeg & Barrett, 2003). Although all 15 mathematics Fellows in the GK-12 program at Mid Western University participated in the first year lesson study, we focus on one of the GK-12 Graduate Fellows, Dave (pseudonym), who participated in lesson study during both years. For data collection for the case study, the research lessons were video-taped. In addition, the authors wrote field notes and Graduate Fellows wrote selected reflections about the video taped lessons. During the second year, pre and post planning sessions were audio-taped and transcribed. Dave was interviewed before and after the second year lesson study as well. Finally, lesson plans and student work from the second year were collected and analysed.

Qualitative data analysis focused on identifying portions of transcripts providing evidence for the development of and the opportunity to develop the elements of mathematical knowledge for teaching (MKT) (See Table 1). To establish inter-rater reliability, the first two authors independently coded data for CCK, SCK, KCS, and KCT. As these elements of MKT were identified, we noted the ways in which those particular elements developed.

RESULTS AND DISCUSSION

In this section, we describe the lesson study focus for each year, and the ways in which one collaborative coach, Dave, developed MKT during both years. Representative quotes provide evidence for each type of knowledge development (ie. SCK, KCS, KCT). We additionally demonstrate how we interpreted the *ways* in which he developed MKT.

For the first year, the topic chosen for the lesson study was interpreting graphs. The coaches and teachers used Calculator Based Rangers (CBR's) to have students graph their motion on graphing calculators as a way of introducing graphical interpretation. CBR's are motion detectors which allow students to see graphs of student motion created in real-time. Dave recounted the lesson by reflecting,

> For sequence, we did the intro where we repeat CBR recordings until the students notice the connection between the teacher's movement and the graph that is displayed. Then we have a short discussion about graphs, axes, data points, etc and give instructions for doing the distance match with their own CBRs. Students then match graphs for ~10 minutes. We then come back together and the students create a graph based on a demonstration (pouring one cup of water into another). A class discussion follows in which we discuss the importance of labels, title, and accuracy of the graphs. We then do another demonstration, and the students create another graph.

After presenting the lesson, Dave wrote in his reflection,

> I wish that I would have given more clear directions at the start. I felt that I left a few details out, but I think the students did a great job!

Dave's reflection indicated that although he had left out details he had hoped to address, he was pleased with the student learning in the lesson. After Dave presented this lesson, the group of Fellows viewed the video tape from the lesson and discussed revisions to the lesson. The second author noted,

> We watched the video, and a lot of the discussion was about the intro. People felt like the intro was maybe too long, the students weren't involved enough, and that it went to in depth (i.e. some of the things Dave explained in the intro could be left for students to first discover on their own when they were experimenting and then discuss after). One suggestion was grabbing a student before class and explaining to them what they needed to do, and instead of Dave walking back and forth in front of the CBR when you're first trying to get the students to realize what is making the graph, have it be one of the students from the class with the hope that this would insight more interest. Another was just to get them the basic idea of what was going on, how the CBR works and then send them out to start experimenting instead of discussing so many details. Dave in the first tape was talking to them…about which direction the graph went when he walked toward the CBR, which direction when he walked away etc, and the suggestion was to just let the students get out there and start discovering this stuff for themselves.

Although Dave had identified in his reflection that his introduction was lacking in clarity, the lesson study revision process revealed that greater changes to the introduction would benefit students. The group decided that students should be allowed to discover concepts instead of Dave telling them about concepts in the beginning of the lesson. In a follow-up interview, Dave confirmed that he had learned from the collaboration process by stating that at first, he thought that explaining distance versus time graphs up front would help students have their Aha! moment about how the graphs were formed. He later learned that students learned more quickly if they were allowed to make discoveries on their own. Thus, the lesson study process and collaboration with other Fellows encouraged Dave to develop knowledge of content and teaching (KCT). KCT developed when other Fellows and Dave identified deficiencies in the lesson, and they agreed upon changes that supported student construction of knowledge.

Another Graduate retaught the research lesson at the end of the school year, and the Fellows again critiqued it. The Fellow wrote in his reflection,

> I'm excited about how this went. This lesson has been practiced and reflected on many times this year by the math fellows…We want students to be able to tell a story from a graph and make a graph from a story…prompting questions have been thought thru. I felt

like the questions were well worded so as to not give away the answers and motivate inquiry learning…Each task is meaningful, one is a springboard into the next.

Thus, the reflection and revision process of lesson study allowed Fellows to critique their lesson with respect to standards- and inquiry-based instruction. Cognitive dissonance, or dissatisfaction with the enaction of the lesson with respect to beliefs about teaching, when experienced within lesson study environment, allowed Fellows to make their implicit beliefs about teaching explicit through discussion and reflection (Olson, Colasanti, & Trujillo, 2006). Fellows could then purposefully plan to align their teaching practices with their emerging beliefs about the benefits of inquiry-based instruction, and thereby improving their KCT.

During the second year of the study, knowledge of content and students (**KCS**) flowed from the teacher to the Fellows as they worked to identify a lesson study topic. The teacher shared student misconceptions which he and other teachers in his department had experienced when teaching slope. In fact, he took an informal poll of the teachers in his department to identify common student misconceptions and areas of difficulty. During the planning meeting (10/9/07) he said,

Steve: I was telling Tom I kind of did a survey of thoughts of what people struggled with in terms of teaching slope intercept form. I got a bunch of different answers, some of them were the same so I didn't really repeat

Dave: Right, yeah

Steve: But I got some people that, you know, their biggest task is alright teaching that the y intercept is an ordered pair. It's a physical spot on the graph. Where you know, when you get your y=mx+b well b is a number but then how does it translate to a physical spot on the graph. Well, we're mathematicians, we know by now because we've been drilled it's on the y axis, but how many kids put it on the x axis?

Dave: Right, yeah.

Steve: Second one, you know, the difference between slope and ordered pair. Slope is a rise over run so you gotta move in the y direction first and the x direction second. Students get that mixed up with, alright how do I graph a physical spot? I go from the origin in the x direction first and then the y direction second. What's the difference? How do we eliminate that, or that confusion or how do we make that better? And then there's a third one, was the concept of going from point to point on a graph, why is it the slope the same from point to point, regardless of the equivalent fractions

As Fellows listened to the teaching problems and issues of teachers and other Fellows, they entered into the space of cognitive dissonance, motivating them to seek ways to improve the teaching of the concepts which had been discussed. Lesson study provided a safe environment for both teachers and Fellows to be vulnerable about their mathematical knowledge for teaching, and thus work collaboratively to

support each other's learning. After discussing the issues with the teacher, the Fellows would often look to research, seek out University mathematics educators, or peruse reform-based curricula for learning tasks which would inform an improved lesson, thus developing knowledge of content and teaching (KCT).

As Fellows searched for resources to improve the lessons that they would co-teach, they became invested in the teaching and learning of mathematics in the teacher's context, translating into a heightened learning environment for MKT. Furthermore, Fellows had an opportunity to immediately transfer theory to practice as they implemented agreed upon reform-based interventions and supporting technologies. Thus the lesson study environment facilitated fertile ground for teacher beliefs and practices to change.

The third element of MKT which the Fellows developed involved specialized content knowledge (**SCK**). Unexpected student questions during the research lesson at times spawned perturbations about the content. During a post-lesson meeting, Dave brought up a teaching episode in which students had replied in an unexpected way to his question about rate after having used CBR's.

Dave: I brought it up because they were like 3 and a third or 2 feet per second and I'm like, well let's think about over all, what's the overall rate? Um. So I asked them what's the overall rate and then they said, oh well 10 feet in 3 seconds, so I said ok, well 10 feet per 3 seconds so how much was it per one second.

Steve: So you divide and get the three and a third.

Dave: So I think I went more of, and it was just kind of the way it happened, but we went more from overall down to unit rate, where that kid said five feet per second so he started with the unit rate and forced it to go the other way.

Thus, an erroneous student response forced Dave to think about rate in unconventional units in order to assist a student with a misconception. The incident prompted Dave to improve his specialized content knowledge.

In summary, this study highlighted several ways in which lesson study may support the development of mathematical knowledge for teaching in collaborative coaches. In the first year, the coaches' development occurred in a lesson study with other coaches, and in the second year, coaches developed along side a teacher. The implication for mathematics education is that lesson study provides a learning environment in which coaches can ground their pedagogical and mathematical learning in the context of the teachers which they support.

Additional information

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References

Ball, D. (2003, February). *What mathematical knowledge is needed for teaching mathematics?* Remarks prepared for the Secretary's Summit on Mathematics, U.S. Department of Education, Washington, D.C.

Cobb, P. & Yackel, E. (2004). Constructivist, emergent, and sociocultural perspectives in the context of developmental research. In T. Carpenter, J. Dossey, & J. Koehler (Eds.), *Classics in Mathematics Education Research* (pp. 208-226). Reston, VA: NCTM.

Fernandez, C. (2005). Lesson study: A means for elementary teachers to develop the knowledge of mathematics needed for reform minded teaching? *Mathematical Thinking and Learning, 7*(4), 265-289.

Lesh, R. & Kelly, A. (2000). Multitiered teaching experiments. In A. Kelly & R. Lesh (Eds.), *Handbook of Research Design in Mathematics and Science Education* (pp.197-230). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Lewis, C., Perry, R., & Murata, A. (2006). What is the role of the researcher in an emerging innovation: The case of lesson study. *Educational Researcher, 35*(3), 3-14.

Moore, C. J. (2003) Partnership for Research in Science and Mathematics Education mission statement. United States: Illinois State University, Biology Department.

NCTM.(2000). *Principles and standards for school Mathematics*. Reston, VA: Author.

National Science Foundation. (2004). Program Solicitation: NSF 04-533. (2004). Retrieved September 30, 2004 from The National Science Foundation Web site: http://www.nsf.gov/home/crssprgm/gk12.

Olson, J. & Barrett, J. (2004). Coaching teachers to implement mathematics reform recommendations. *Mathematics Teacher Education and Development. 6,* 63-78.

Olson, J., Colasanti, M., & Trujillo, K. (2006). Prompting growth for prospective teachers using cognitive dissonance. In J. Novotna, H. Moraova, M. Kratka, & N. Stehlikova (Eds.) *Proc. 30th Conf. of the Int. Group for the Psychology of Mathematics Education* (Vol. 4, pp. 281-288). Prague, Czech: Charles University.

Pothen, B.E., & Murata, A. (2007). Transforming teachers' knowledge: The role of lesson study in preservice education. In T. Lamberg & L. R. Wiest (Eds.), *Proc. 29th Conf. of the North American Chapter of the Int. Group for the Psychology of Mathematics Education* (pp. 999-1006). Stateline (Lake Tahoe), NV: University of Nevada, Reno.

Presmeg, N., & Barrett, J. (2003). Lesson study characterized as a multi-tiered teaching experiment. In N. Pateman, B. Dougherty, & J. Zilliox (Eds.), *Proc. 27th Conf. of the Int. Group for the Psychology of Mathematics Education* (Vol. 4, pp. 47-54). Honolulu, USA: PME.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Education Review, 57(1).* 1-22.

Stigler, J. & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. New York: The Free Press/Simon & Schuster.

Takahashi, A., & Yoshida, M. (2004). Ideas for establishing lesson-study communities. *Teaching Children Mathematics, 10*(9), 436-443.