Learning Together: Practice-Centred Professional Development to Enhance Mathematics Instruction

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Elementary teachers were involved in a two-year grant focused on professional development using lesson study processes to increase their understanding of mathematics content and effective mathematics pedagogy. The primary research questions focused on how 16 elementary teachers described their professional growth after being involved in lesson study in a professional learning community with other teachers and university professors and how they described the impact the program had on their teaching of mathematics. Case study methodology provided the tools for researchers to study complex phenomena within a professional learning community setting. Collected data included interviews of selected teachers focused on the lesson study process, teacher journal reflections, and recordings of individual teacher discussions of video taped segments of their teaching. Data indicated the participants valued collaboration within the community of learners and a change in practice through a focus on student discourse, student thinking, and questioning strategies. The majority of teachers demonstrated the change in practice; however, not all teachers demonstrated such growth.

Keywords: · lesson study · professional development · mathematical knowledge for teaching · professional learning communities · teacher knowledge of mathematics pedagogy

Background

While school district administrators have been directed to involve teachers in professional development; ensuring ongoing professional growth for teachers that improves student achievement has been problematic. Darling-Hammond (2009), Darling-Hammond, Bransford, LePage, and Hammerness (2007), and Goodlad (1990) cited research that on the one hand recognises teachers as the key to better learning for students, and on the other hand notes that reform efforts have fallen short of the goal to improve instruction and student learning. With teacher knowledge of mathematical concepts in mind, Ball, Thames, and Phelps (2008) emphasised teachers should be equipped with specialised content knowledge of mathematics that prepares them to meet the challenges that occur when students are involved in learning the content and solving problems. In order to develop the knowledge of mathematics needed for reform-minded teaching, Fernandez (2005) posits that teachers need to be engaged in a practice-centred form of professional development like that provided in the processes of Japanese lesson study. In relation to Fernandez's (2005) research, our research in this study indicates that the challenges of planning professional development to help teachers develop a deeper understanding of mathematical concepts and effective teaching strategies can be met in the cycle of Japanese lesson study within the professional learning community.

Review of Literature

The theoretical framework for this study is rooted in the model of a professional learning community within a culture of continuous learning for teachers who investigate students' response to lessons.. Two frameworks are integrated into this study, beginning first with Hord's (1997a) framework for the five dimensions of a professional learning community (PLC), and the cyclical professional development processes in Japanese lesson study (Kazemi, Elliott, Hubbard, Carroll, & Mumme, 2007). Hord's framework is the result of her extensive review of literature related to schools involved in the processes for a professional learning community. Her definition of a PLC as a professional staff learning together with a focus on improving student learning is a consequence of this review. The conceptual framework for lesson study is based on research that highlights student response to structured problem-solving lessons (Groves, Doig, Widjaja, Garner, & Palmer, 2013).

Professional Learning Communities

The five attributes or dimensions that Hord (1997a, 1997b, 1998, 2004; Hipp, Huffman, Pankake, & Olivier, 2008) suggested to characterise professional learning communities are revised and adapted in the following:

1. Supportive and shared leadership: Collegial and facilitative participation of the principal who shares leadership, power, and authority through involving staff in decision making.
2. Shared values and vision: Shared vision that is developed from a steadfast commitment on the part of staff to students' learning and one that is consistently articulated and referenced in the staff's work.
3. Collective learning and application of learning: Collective learning among staff and learning applications to solutions for addressing the needs of the students.
4. Supportive conditions: Physical conditions and human capacities that continually support the operation of a PLC through a collegial atmosphere and collective learning.
5. Shared practice: Visitation and review of each teacher's classroom behavior by colleagues as feedback and assistance activities to actively support both individual and a community improvement. (Hipp et al, 2008; Hord, 1997a, 1997b, 1998, 2004)

Within the dimensions and vision of how a PLC functions are descriptors such as reflective dialogue, a collective focus on student learning, collaborative teaming, results orientation, and the possession of a collective resolve (Hipp, et al, 2008). Dufour and DuFour (2003) describe the professional development community within the school as an entity with a unified vision that can provide the administrators, teachers, and students with the focus and direction needed for increasing student achievement. The reflective dialogue and other processes of the professional learning community are stimulated within a culture of trust and a culture of change that needs to be supported by the principal and other school leaders (DuFour & DuFour, 2003; DuFour, 2011).

As DuFour, Eaker, and DuFour (2005) suggested, the use of PLCs is the best, least expensive and most professionally rewarding way to improve schools. In both education and industry, there has been a prolonged, collective cry for such collaborative communities for more than a generation. Such communities hold out immense, unprecedented hope for schools and the improvement of teaching. However, an effective system of teacher collaboration within a professional learning community does not emerge spontaneously or by invitation (DuFour & Eaker, 1998). The concept of systemic reform that characterises the professional learning community is well entrenched in the model for lesson study outlined by Chokshi and Fernandez (2005). They suggested building a professional knowledge base through distinct processes for teacher collaboration and discussion open to criticism and revision. Within the model Chokshi and Fernandez described is the concept that a critical piece for the professional role of teachers includes the re-envisioning and altering of their professional role.

Historically, since the early 1990s a new standard for K-12 teacher professional development has been evolving with the professional learning community (PLC) (DuFour & Eaker, 1998; Fullan, 1998; Hord, 1997a, 1997b; Senge et al., 2000). The term learning community entered the educational discussion soon after the publication of Senge's (1990) book *The Fifth Discipline* called for a transformation of corporations into learning organisations. Senge's recommended processes of team learning that were focused on a discussion of goals and problems in which "people are continuously learning how to learn together" (p.3) appealed to educators. When the term *learning communities* entered the educational literature (DuFour & Eaker, 1998; Fullan, 1998; Hord, 1997a, 1997b; Senge et al., 2000) it was transformed to *professional learning communities* by a group of collaborators which included DuFour, Eaker, and DuFour (2005). Through their book *On Common Ground: The Power of Professional Learning Communities,* the concept of the PLC entered the educational mainstream and school leaders began to re-conceptualise schools.

While the educational literature gives definition, description, and examples of what schools that incorporate the processes of a professional learning community should look like, the documentation of professional development for teachers within a community of learners often lacks details about the ongoing processes, especially within a discipline. Hipp, Huffman, Pankake, and Olivier (2008) posit that ideas about the professional learning community might not be transferrable from one school to the next, but they note that educators are looking for ways to embed processes that promote continuous improvement for student learning. Professional development within a learning community requires informed and purposeful action that is focused on creating a culture of learning for teachers and students, but strategies for structuring and supporting a learning culture may not be clear to educational leaders who wonder what teachers should do when they meet together to reflect on student learning (DuFour & DuFour, 2003). For many educators it is not enough to give time for teachers to focus on student work and instruct them to look for ways to improve instruction (DuFour & Eaker, 1998). Most teachers need guidance and a clear understanding of specific strategies they can follow within a supportive structure where previously isolation has been the norm. The concept of collaboration to improve student learning is a relatively new concept in the United States, and for teachers especially, it can be a difficult change to manage effectively (DuFour, Dufour, & Eaker, 2008).

While educators and researchers (Hipp, et.al, 2008) in the United States have recently begun to investigate strategies, structures, and supports for professional learning communities that can transform instruction, collaboration with peers has been a common mode of practice in other countries (Hamos et al. 2009; Wong, Britton & Ganser, 2005). Integrated with the framework of the PLC is the Japanese lesson study model (Chokshi & Fernandez, 2005) of professional development with a focus on student learning. Fernandez (2005), a proponent of lesson study, argued that lesson study can afford teachers opportunities to learn to plan mathematics instruction in ways that encourage reform-minded teaching. Within the lesson study model is a clear set of principals or hypotheses about how teachers learn. Stigler and Hiebert (1999, p.150) introduced the steps that lesson study embodies with the caveat that they might need to be modified to work in the United States. Most people would welcome a model for professional learning communities that need to be revisited rather than to have no model at all.

Lesson Study

Adding the processes of Japanese lesson study to the professional learning community may provide a structure for effectively addressing student achievement in mathematics. A study conducted by Robinson and Leikin (2012) in Israel identified the mechanisms of change within a team of elementary mathematics teachers involved in lesson study in the teaching of mathematics. Results indicated that lesson study enhances teachers' awareness of student learning through observations and reflections on teaching and learning. Lewis and Perry (2014) also found enhanced knowledge for mathematics teachers involved in reflecting on mathematical tasks after observing lessons of students in grades 2 through 5. In the Lewis and Perry study, teachers involved in lesson study processes were also supported by a mathematics

resource kit. These studies indicated that professional learning communities involving elementary teachers who teach mathematics may be beneficial; however, additional research is needed in this area to better understand the benefits and challenges in professional learning communities which employ the lesson study process (Groves, Doig, Widjaja, Garner, & Palmer, 2013).

After a brief history of Japanese lesson study which began with mandated and well-funded initiatives, that were organised by teachers in school-based settings, Groves, et al. (2013) noted that world-wide attention for lesson study as professional development became more focused through Yoshida's (1999) doctoral dissertation and Stigler and Hiebert's (1999) research and writing about Japanese structured problem-solving lessons. Groves, et al. (2013) drew on lesson study research similar to that above to develop a more formal listing of four primary components in the processes of Japanese lesson study which include:

- formulation of over-arching school goals related to students' learning and long-term development;
- group planning of a research lesson addressing these goals;
- one team member teaching the research lesson while the planning group and others observe in order to gather evidence of student learning; and
- the post-lesson discussion where the planning group and other observers (usually including an 'outside expert') discuss and reflect on the evidence gathered during the lesson, using it to improve the lesson, the unit, and instruction more generally (Lewis & Perry, 2008, p. 366 as cited in Groves, Doig, Widjaja, Garner, & Palmer, 2013, p.10).

Stigler and Hiebert (1999) described a strong example of learning community within Japanese schools where teachers participate in lesson study groups as ongoing professional development. In lesson study teachers begin with a common goal for the study, collaborate in groups to study resources and plan lessons, observe the lessons being taught, analyse the student responses to the lesson, and debrief and revise the classroom lessons in accordance with the student responses (Lewis, Perry, Hurd, & O'Connell, 2006). The focus on student learning is obvious in Stigler and Stevenson's (2001) description of lesson study. According to Tepylo and Moss (2009), "In lesson study - a professional development method credited with improved student learning in Japan over the last 50 years - teachers cyclically plan a lesson together, observe the lesson implemented in a real class, scrutinise student learning, and then re-teach an improved lesson" (p. 2). Critical examination of student understanding is a key ingredient within this professional learning community. Our goal here is to enlarge the discussion of professional learning communities to include the cyclic processes of lesson study within a community of teachers from across a school district.

About the Study

The study described here focused on a group of 16 elementary teachers who participated in a two-year professional development project that was a partnership between a rural school district and a university in the southern United States. Funding for the program was provided at the state level through a federal grant. Teachers of mathematics in grades 3-5 applied to participate in the program and were selected based on their limited coursework in mathematics at the university level. Whenever possible, teams of teachers from the same school were chosen to participate in the project with the thought that proximity to other project participants might improve opportunity for collaboration.

Each summer teachers participated in an institute focused on increasing their knowledge and understanding of mathematical concepts of number sense and problem based learning. Four grade level groups, consisting of four teachers in each group, wrote a unit of mathematics lessons and chose a problem-based research lesson to focus on in the fall. During the summer teachers were also introduced to the cyclical processes for lesson study and meetings in the fall afforded the opportunity to apply the processes of lesson study in classrooms.

Teachers met four times each fall semester for the lesson study process which included teaching the research lesson. Before each research lesson the grade level group of teachers met to discuss the setting, unique student needs, and aspects observers needed to focus on during the lesson. Then the research lesson teacher, other teacher group members, and a university professor went to the classroom of the research lesson teacher to observe the student response to the lesson. During the lesson observers took notes regarding student engagement and response to the lesson. After the lesson, the teachers and university professor met again to discuss the lesson and the student response to the lesson. The research lesson teacher began the discussion regarding student response to the lesson followed by observers discussing their observations of student responses. After the reflection on student learning, the discussion focused on how the lesson might be improved before the next teacher in the group would teach the lesson in their classroom. Teachers then revised the written lesson, noting any changes that might be needed, such as differing manipulatives or adjustments to previous lessons that might better prepare students for the teaching of the research lesson. The same processes were applied each time a member of the group taught the research lesson. Revisions to the research lesson were continuous throughout the cycle of teaching, and revision of the research lesson was based on student response and understanding. Each teacher participated in this process each year. Thus, every year each teacher taught the group's research lesson while group members observed, observed the three other teachers in their group teaching the research lesson, and worked collaboratively to revise the research lesson after each teaching. In addition to participating in lesson study, the teachers also chose a short lesson to record and then view and discuss in their group. For example, some teachers focused on a particular part of the lesson such as how they used higher order questions to guide student thinking about the lesson solution. Teachers viewed the lesson video in their groups and reflected on how to improve student understanding.

Research Questions

The research questions that guided our study were:

1. How do elementary teachers describe their professional growth after being involved in lesson study as part of a professional learning community?
2. How does involvement in a professional development project focused on student understanding of mathematics influence elementary teachers' instructional practices?

Context and Methodology

Each year the project director and coordinators planned a professional development program in which third-fifth grade elementary teachers attended 11 day-long sessions during the summer. The first eight days were focused on increasing teacher participants' mathematical concept understanding of number sense. The last three days focused on the cyclical process of lesson study. The teachers worked together to use the content knowledge they had gained to write a mathematics unit that would be implemented in their classrooms in the coming academic year. One of the problem solving lessons from the unit was selected to be the lesson study research lesson and was more fully developed.

In the model for lesson study used in the professional development community of this study, a facilitator for each group guided teachers in the lesson study process to ensure critical inquiry before and after the lesson observation. The research lesson chosen involved presenting a problem to students without first demonstrating the process for the solution. Students in groups participated in problem solving and recorded their findings on a large piece of chart tablet paper. Then each group presented their solutions to the problem to the rest of the class. The teacher placed the chart tablet pages side by side and students discussed the multiple solutions possible through guided questions by the teacher. Teachers might ask questions such

as, "How do you know? What makes you think so? Can you convince me? Have you convinced the members in your group?" If students explained in a rather superficial way, teachers might ask, "What did you notice that made you think of this? Can you say more about that?" In order to solidify student understanding, teachers also guided students in higher level thinking by asking, "Now what would happen if … (a certain condition was different)? How might your approach change?" During the lesson study process teachers were engaged with students in discussing mathematics for understanding in order to work through problems rather than just completing exercises.

Case Study Method

In ill-structured domains such as teaching and learning, discerning quality is a complicated endeavour and requires attention to data collected from multiple perspectives for evaluating multiple facets of an issue. Our choice of the qualitative case study enables us to use a variety of data sources to clarify an understanding of the phenomenon of teacher development in the two-year period of the project. Furthermore, Lincoln and Guba (1985) asserted that the case study was fitting for a continuous reporting process where information is gathered during the inquiry to inform respondents and audiences. We defined the two-year professional development project as our case, "a unique entity with its own particular meaning and its own constellation of relationships emerging from and related to the context in which it exists" (Erlandson, Harris, Skipper, & Allen, 1993, p. 85).

Purposive sampling (Bogdan & Biklin, 1982) was used for the study. Teachers who participated in the study were involved in a two-year professional development program. All teachers in the study had participated in one to two years of the program and represented a cross-section of the total population of third-fifth grade teachers from the school district in terms of age, ethnicity, and gender. Of the 16 teachers who were asked to participate in the study, all participated. The teachers were employed in the same public school district in the same region in which the university is located. In order to compensate for any bias and encourage teachers to provide honest feedback regarding their experience with the professional development program, the researcher who was a consultant for the program and had limited contact with the participants conducted the interviews with the selected teachers.

Of the 16 teachers, 13 participated two years in the program, two missed the first summer institute, but participated for the remainder of the two-year program beginning in the fall of the first year (replacing two teachers who had withdrawn after the first summer institute), and one participated throughout the second year. The teachers varied in the grade level taught according to when they began the program, as 10 taught third grade, five taught fourth grade, and one taught fifth grade. Two males and 14 females participated, with 10 of those teachers being White and five Hispanic.

Data Sources

In order to address our questions, we conducted semi-structured interviews with purposefully selected teachers (Seidman, 1998; Spradley, 1980), videotaped teachers discussing self-selected video clips of their teaching, and analysed teachers' journal reflections of the video clips. One source of data during the fall of the second year was the videotape of discussions about the self-selected video clips of teaching. The teachers worked in grade level groups consisting of four participants. Teachers self selected an aspect that they wanted to improve within the teaching of mathematics. They videotaped themselves teaching and selected a 3-5 minute segment of the video to share with members of their group. Each teacher shared the self-selected video clip, informing others in their group of the teaching aspect they wanted to improve. During and after sharing the video clip, group members provided feedback in relation to the identified teaching aspect. The groups were provided with a format for viewing and analysing the videos. Teachers shared video clips of the teaching of two different lessons, one each during the second and last meeting of the fall semester. Each of the discussions of the video taped lessons was video taped. Five video clips of the discussions were purposefully selected to analyse based on a

representation of different groups, the quality of the video, and groups following the criteria for analysing the video.

A second source of data consisted of the journaling of reflections of the video clips and discussions. Before sharing the video clips with their groups, teachers wrote a reflection of their teaching based on the video clip they selected. After viewing the video clips and the discussion, the teachers wrote a second reflection.

The third source of data consisted of interviews of four selected teachers. All of the interviews were individually conducted, video taped, and transcribed. The teachers were emailed the questions in advance to allow them time to reflect on their experience in the professional development program. The interviews lasted approximately 45 minutes and were conducted in person in a separate room during the last meeting of the spring semester of the second year. Of the teachers interviewed, three taught third grade and one taught fourth grade. Two teachers were male, two were female, two were Hispanic, two were White, and three interviewees had participated in the program throughout the two year period, while one started the program at the beginning of the first fall semester and participated in the program during the remainder of the year.

Analysis

To code the discussions of the video clips, we turned to the three criteria developed by Sherin, Linsenmeier, and van Es (2009) as a guide. The first criteria focused on understanding student thinking. We modified the highest level of the first criteria of "Student ideas identified as objects of inquiry and a sustained attempt was made to make sense of student thinking" (p. 219) to also include the use of student discussion/responses "to make sense of student thinking" as an indicator of effectiveness of the identified professional development area.

We used the highest level of the second criteria, "Discussion of student thinking primarily focused on substantive mathematical ideas" (p. 219) as it was originally stated. The criteria focused on teachers closely examining student ideas and content knowledge.

The highest level of the third criteria, "Teachers consistently respond to and build on each other's ideas; teacher comments support joint sense making of events in video" (p. 219) was modified to include "substantively build on" and "offering evidence of why or how in the comments". This criteria focused on teachers collaborating and sharing knowledge. One discussion of each teacher's video clips was randomly selected and coded using these three criteria. The following provides information as to the modifications of the criteria (see Table 1).

Table 1

Criteria	Developed by Sherin, Linsenmeier, and van Es (2009)	Revised
Understanding student thinking	Student ideas identified as objects of inquiry and sustained attempt made to make sense of student thinking	Student ideas and student discussion/responses identified as objects of inquiry and sustained attempt made to make sense of student thinking
Examining student ideas and content knowledge	Discussion of student thinking primarily focused on substantive mathematical ideas	
Teacher collaboration and sharing knowledge	Teachers consistently respond to and build on each other's ideas; teacher comments support joint sense making of events in video	Teachers consistently respond to and substantively build on each others' ideas offering evidence of why or how in the comments; teacher comments support joint sense making of events in video

We first analysed the journaling of reflections. Based on the analysis, questions were included in the interview on aspects not addressed or that needed further clarification. All sources of data, the videos of participants' discussion of the video clips, the journaling of reflections, and the interviews, were analysed using a process of searching for patterns and relationships to identify codes and themes (Hatch, 2002). The data was analysed and coded for themes using a process of open coding and selective coding (Harry, Sturges, & Klingner, 2005). To establish trustworthiness within the coding process, we coded the videos, reflections, and interviews individually and then compared our interpretations and developed consensus about the codes within each of the different sources of data. Once the initial codes were developed, we compared the codes across the various sources of data.

Findings

From the analysis of the interviews, journal reflections, and videos, we discovered trends within the selective codes pertaining to professional growth as a result of involvement in a professional learning community that practiced the cyclical processes of Japanese lesson study. In response to questions regarding how teachers described their professional growth after being involved in the professional development project and how that participation impacted teachers' instructional practices and student learning, two themes emerged. Teachers indicated the importance of collaboration with peers focused on student response to lessons as beneficial to their professional growth. They also indicated there was a change in their practice of the teaching of mathematics to children as a result of participation in the project.

Collaboration

All of the teachers interviewed emphasised the positive influence of collaborating with peers to develop lessons, teaching with observers present as another set of eyes, and dialoguing about students' responses to learning. While most teachers were unsure about having observers in their classroom during a lesson before they began the lesson study processes, during the interviews, each of the teachers discussed the value of being able to collaborate with others to improve the problem based lessons and teaching of mathematics. One teacher commented on this phenomenon in the following statement, "Amazing experience! I feel that the biggest pro was the ability to collaborate with my peers in learning from one another" (Teacher interview,

2011). Another teacher provided examples of how the collaboration that began as a result of the project had grown to include other teachers in the building and in other schools. The lesson study processes of collaborating, dialoguing about practice, and sharing ideas for improving instruction with other teachers was also described as a positive professional development experience in the journal reflections. Half of the teachers included statements about the importance of collaboration and dialogue in at least one of their journal reflections. Nine of the 16 teachers reflected on the positive influence of peer support and affirmation. In addition, half of the teachers wrote about the positive effect of receiving recommendations regarding their teaching as a result of the collaboration. One participant wrote:

> I love reflecting with the group… They notice things that I don't see. As teachers we tend to focus on what else needs to be done or what they [students] did wrong and how much they need to learn. When other people view your classroom and your teaching they tend to see what they [students] are doing well. It has helped me a lot (Teacher journal reflection, 2010).

This quote exemplifies teachers' reflections on the advantages of collaborating with others in the project.

Change in Practice

All of the teachers interviewed indicated a change in practice in the way they taught, that involved a deeper understanding of the importance of using problem based instruction to strengthen students' conceptual understanding of mathematics. In addition, all teachers emphasised the effect of teacher reflection and dialogue with other teachers on instruction in changing, and thus improving, their practice. Teachers also indicated that being involved in the program provided instructional strategies they could use in teaching mathematics to children that came out of some of the sharing sessions. One teacher described how participation in reflection with other teachers motivated her to question and change the way she had taught mathematics:

> As we got into this we could just see a different way of teaching, you know, just how it even made me question myself. I love teaching math, and I like teaching these kids this and that. But getting into this program and seeing a different way of teaching it made me question myself, you know. It was really good because it made me better myself (Teacher interview, 2011).

Such statements are an indication of the powerful influence of involvement in a professional community that emphasises pedagogy and student understanding.

A change in practice cited by the teachers who were interviewed indicated that their improved content knowledge equipped them with a deeper understanding for meeting the instructional needs of the students. Teachers who were interviewed indicated that their own understanding of mathematical concepts on a deeper level assisted them when they were working with students. They were better prepared to help students connect mathematical concepts for the construction of mathematical meaning. One teacher provided the following thoughts:

> I have been able to tie things together for my students that I would not have been able to do before, bring concepts together that I wouldn't have been able to do before. So yeah, I think it has been a huge difference in the way I teach math (Teacher interview, 2011).

Thus, teachers indicated their mathematics content knowledge was strengthened and their understanding of mathematical relationships and connections were deepened which lead to positively impacting their teaching of mathematics to children.

In addition, the respondents spoke of their change in practice through a focus on student discourse, student thinking, and improved questioning strategies. Examples of this included an increase in the use of higher level questioning where students were encouraged to explain their thinking, describe their approach to problem solving, and discuss problem solving processes. The confidence teachers had in their own mathematical understanding of concepts helped them to allow students' diverse ways for problem solving. Teachers described how such change in practice has not only resulted in a growth in students' understanding of mathematics, but students have shown teachers new ways to solve problems. As the groups of students worked

together their discourse provided an opportunity for students to learn from each other. In discussing teacher and student learning about mathematics, one teacher shared these insights:

> They have created and shown me many new ways to solve various problems in mathematics, which I never saw from their eyes. Their justification to their thinking is amazing which allows other students to have a better understanding in regards to the concept (Teacher interview, 2011).

This description of a change in practice demonstrates the value of providing an opportunity for student discourse to promote understanding as a result of participation in the project. Teachers described a change in practice that results in a promotion of students' higher-level thinking and a deeper understanding of mathematical concepts.

As indicated by their responses, teachers discussed a change in practice as a result of their involvement in the professional development that impacted their teaching, thinking about teaching, and student learning. Analysis of the journal reflections also indicated a change in the practice of teaching mathematics. In the journal reflections, 11 of 16 (69%) teachers identified a deeper understanding of mathematics regarding the teaching of mathematics in one or more areas of student understanding and thinking, justification, and problem solving as well as questioning strategies that would extend student understanding. Analysis of the video clips also supported this finding with 66% of teacher responses categorised at the medium or high level for focusing on understanding student thinking.

However, one conflicting statement of a teacher interviewed occurred when the participant admitted that participation in the program had translated to students' deeper understanding of mathematics; yet the participant claimed that some students cannot understand the *why* of a particular concept without a *trick* to help them get the answer to a problem. Other data supported the focus on lower level thinking of students by some of the teachers. In the journal reflections, five out of 16 (31%) teachers demonstrated a focus on lower level thinking such as memorising, steps to use, and *tricks* rather than a deep understanding of the mathematics. Analysis of the video clips indicated 34% of teacher responses were categorised at the low level for focusing on understanding student thinking. This finding supports the focus on student lower level thinking by some teachers in their journal reflections.

To summarise, teachers interviewed indicated that involvement in the PLC resulted in a positive change in practice in their teaching of mathematics to children. In addition, all of the teachers interviewed emphasized the importance of collaboration for their professional development growth, which was also supported by many of the journal reflections of which all the teachers wrote. However, analysis of the interviews and video clips indicated not all teachers could describe examples of substantial growth in their practice nor could they demonstrate this attribute in their discussions of student work.

Discussion

During this study, we reflected on the shared experience of elementary teachers from a school district who were involved in a two-year professional development community involved in the processes of lesson study. As researchers, we focused on the professional growth of the teachers and the impact participation in the project had on their teaching of mathematics to children. The findings of this study revealed insights about the teachers' shared perspectives of the ways they plan and implement instruction to meet students' diverse needs. The teachers were unified in describing how the PLC supported their professional development in changing their instructional approach from superficial rote learning to more in depth mathematical understanding. However, when we scrutinized the lesson videos, at least two teachers lacked the ability to provide evidence of substantive growth in the teaching of mathematical concepts to children. This finding may provide some insight into the design and support needed for professional learning communities when educators are interested in guiding teachers toward the change in practice that equips students with a stronger conceptual understanding of mathematics.

In examining how teachers describe their professional growth after being involved in a professional learning community, collaboration was identified as a major influence and support

by all of the teachers. The sharing of ideas, planning lessons together, and reflecting on teaching and student learning in a supportive environment appears to have been critical to teacher growth. As indicated by Lesley, Gee, and Matthews (2010), finding ways for teachers to collaborate, such as with collegial coaching or mentoring, is needed to help support teacher growth. However, in spite of an increased awareness of the importance of ongoing professional development within a learning community, teachers who have the opportunity to meet together may not have a structure for collaboration and reflection. Building a community of teachers who are focused on student understanding by developing and revising lessons for problem–based learning in mathematics might offer such a structure. Collaboration in a community of learners who use a structure such as lesson study to focus on student learning may help to move teachers towards a change in practice.

We found that the teachers appreciated the time and support that was provided to engage with other educators involved in the project, both in their school district and at the university level. Unfortunately, they indicated the realities of their job did not provide the time and supportive structure needed to deeply examine teaching and student learning as we had in the project. For example, one teacher explained, "I do feel like it works in many ways but with administrators not trained in lesson study they do not see the positive effects and learning that we see during this process" (Teacher interview, 2011). A continued discussion is needed regarding how teachers can be supported in their professional development and the knowledge and skills needed by administrators to make teacher professional growth a reality. Educators at each level need to understand lesson study and be advocates for this type of professional development, from the local level with teachers and administrators through the state level.

Although all teachers who were involved in a community of learners for one to two years and had indicated growth in their professional development, their understanding and facilitation of guiding students toward higher level thinking is still developing. The challenge for teachers is to know how to listen to students and use the information gained to increase students' mathematical understanding. A structure such as lesson study provides teachers with assistance from colleagues who have observed the lesson taught, time for reflection about the lesson that improves content and delivery, and opportunity to revise the lesson for enhanced student learning. Ultimately, the cyclical processes of lesson study within a professional learning community may offer a more purposeful structure for ongoing professional development for teaching mathematics for greater student achievement.

The results of this study encourage us to build on what is known about professional development and how teachers grow in their craft. Additional inquiry is needed for how substantive teacher growth occurs for long-term teacher change in practice. The findings of this study indicate that while involvement in professional development to deepen teachers' understanding of mathematics and their knowledge of how to teach mathematics is important, participation in the continuous processes of a professional learning community for more than two years may be needed in order to change instructional practice.

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References

Ball, D. L., Thames, M., &.Phelps, G. C. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59,* (5) 389-407.

Bogdan, R. C. & Biklin, S. K. (1982). *Qualitative research for education: An introduction to theory and methods*. Boston, MA: Allyn & Bacon.

Chokshi, S. & Fernandez, C. (2005). Reaping the systemic benefits of lesson study: Insights from the U.S. *Phi Delta Kappan, 86,* (9) 674-680.

Darling-Hammond, L. (2009). *The flat world and education*. New York, NY: Teachers College Press.

Darling-Hammond, L., Bransford, J., LePage, P., & Hammerness, K. (2007). *Preparing teachers for a changing world: What teachers should learn and be able to do.* San Francisco, CA: Jossey-Bass.

DuFour, R., & Eaker, R. (1998). *Professional learning communities at work: Best practices for enhancing student achievement.* Bloomington, IL: Solution Tree.

DuFour, R. (2011). Work together but only if you want to. *Phi Delta Kappan, 92*(5), 57-61.

DuFour, R., & DuFour, R. B. (2003). Building a professional learning community. *School Administrator, 60*(5), 13.

DuFour, R., DuFour, R., & Eaker, R. (2008). *Revisiting professional learning communities at work.* Bloomington, IN: Solution Tree.

DuFour, R., Eaker, R., & DuFour, R., (Eds.) (2005). *On common ground: The power of professional learning communities.* Bloomington, IL: Solution Tree.

Erlandson, D. A., Harris, E. L., Skipper, B. L., & Allen, S. D. (1993). *Doing naturalistic inquiry: A guide to methods.* Thousand Oaks, CA: Sage.

Fernandez, C. (2005). Lesson study: A means for elementary teachers to develop the knowledge of mathematics needed for reform-minded teaching? *Mathematical Thinking & Learning*, 7(4), 265-289. doi:10.1207/s15327833mt10704_1

Fullan, M. (1998). Leadership for the 21st century: Breaking the bonds of dependency. *Educational Leadership, 55*(7), 6-10.

Goodlad, J. (1990). *Teachers for our nation's schools*. San Francisco, CA: Jossey-Bass.

Groves, S., Doig, B., Widjaja, W., Garner, D., & Palmer, K. (2013). Implementing Japanese lesson study: An example of teacher-researcher collaboration. *Australian Mathematics Teacher, 69*(3), 10-17.

Hamos, J. E., Bergin, K. B., Maki, D. P., Perez, L. C., Prival, J. T., Rainey, D. Y., & VanderPutten, E. (2009). Opening the classroom door: Professional learning communities in the math and science partnership program. *Science Educator, 18*(2), 14-24.

Harry, B., Sturges, K. M., & Klingner, J. K. (2005). Mapping the process: An exemplar of process and challenge in grounded theory analysis. *Educational Researcher.* 34(2), 3-13.

Hatch, J. A. (2002). *Doing qualitative research in education settings.* Albany, NY: State University of New York Press.

Hipp, K. K., Huffman, J. B., Pankake, A. M., & Olivier, D. F. (2008). Sustaining professional learning communities: Case studies. *Journal of Educational Change.* 9(2), 173-195.

Hord. S. (1997a). *Professional learning communities: Communities of continuous inquiry and improvement.* Austin, TX: Southwest Educational Development Laboratory.

Hord, S. (1997b). *Professional learning communities: What are they and why are they important?* Austin, TX: Southwest Educational Development Laboratory.

Hord, S. (1998). *Creating a professional learning communities: Cottonwood Creek School.* Austin, TX: Southwest Educational Development Laboratory.

Hord, S. (Ed.). (2004). *Learning together—leading together.* NY: Teachers College Press.

Kazemi, E., Elliott, R., Hubbard, A., Carroll, C., & Mumme, J. (2007). Doing mathematics in professional development: Theorizing leader learning with and through sociomathematical norms (pp. 796-803). In T. Lamberg, T. & L. R. Wiest (Eds.), *Proceedings of the annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*, Stateline (Lake Tahoe), NV: University of Nevada, Reno.

Lesley, M., Gee, D., & Matthews, M. (2010). Separating the chaff of bureaucracy from the grain of pedagogy: Creating quality new teachers in the age of accountability. *Teacher Education Quarterly, 37*(2), 33-51.

Lewis, C. & Perry, R. (2014). Lesson study with mathematical resources: A sustainable model for locally-led teacher professional learning. *Mathematics Teacher Education and Development,* 99-116.

Lewis, C., Perry, R., Hurd, J., & O'Connell, M. P. (2006). Lesson study comes of age in North America. *Phi Delta Kappan.* 88(4), 273-281.

Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic inquiry.* Thousand Oaks, CA: Sage.

Robinson, N. & Leikin, R. (2012). One teacher, two lessons: The lesson study process. *International Journal of Science & Mathematics Education* 10(1), 139-161.

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization.* New York, NY: Doubleday.
Senge, P., Cambron-McCabe, N., Lucas, T., Smith, B., Dutton, J., & Kleiner, A. (2000). *Schools that learn: A fifth discipline fieldbook for educators, parents, and everyone who cares about education.* New York, NY: Doubleday/Currency.
Seidman, I. (1998). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. New York, NY: Teachers College Press.
Sherin, M. G., Linsenmeir, K. A., & van Es, E. A. (2009). Selecting video clips to promote mathematics teachers' discussion of student thinking. *Journal of Teacher Education, 60*(3), 213-230.
Spradley, J. (1980). *Participant observation*. New York, NY: Harcourt Brace Jovanovich.
Stigler, J. W. & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom.* New York, NY: Free Press.
Stigler, J. S. & Stevenson, H. S. (2001). How Asian teachers polish each lesson to perfection. In M. Gauvain, & M. Cole (Eds.), *Readings on the development of children* (pp. 181–194). New York, NY: Worth.
Tepylo, D., & Moss, J. (2009). Examining the important features of lesson study. *Conference Papers -- Psychology of Mathematics & Education of North America*, 1. Retrieved from EBSCO*host*.
Wong, H. K., Britton, T. & Ganser, T. (2005). What the world can teach us about new teacher induction. *Phi Delta Kappan.* 86(5), 379-384.

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