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Fanning the Flames of Greatness

In This Issue, We Offer Ideas for Extending Your Passion to Other Mathematics Professionals

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CORRECTION FROM WINTER 2008 JOURNAL
The Winter 2008 *NCSM Journal* omitted co-author Daniel Clark Orey from the byline of the article, "It Takes A Village: Culturally Responsive Professional Development and Creating Professional Learning Communities in Guatemala." Dr. Orey is a professor of mathematics and multicultural education at California State University, Sacramento. We regret the omission.

Purpose Statement

The purpose of the National Journal of Mathematics Education Leadership is to advance the mission and vision of the National Council of Supervisors of Mathematics by:

- Strengthening mathematics education leadership through the dissemination of knowledge related to research, issues, trends, programs, policy, and practice in mathematics education
- Fostering inquiry into key challenges of mathematics education leadership
- Raising awareness about key challenges of mathematics education leadership, in order to influence research, programs, policy, and practice
- Engaging the attention and support of other education stakeholders, and business and government, in order to broaden as well as strengthen mathematics education leadership

Keeping Teacher Learning of Mathematics Central in Lesson Study

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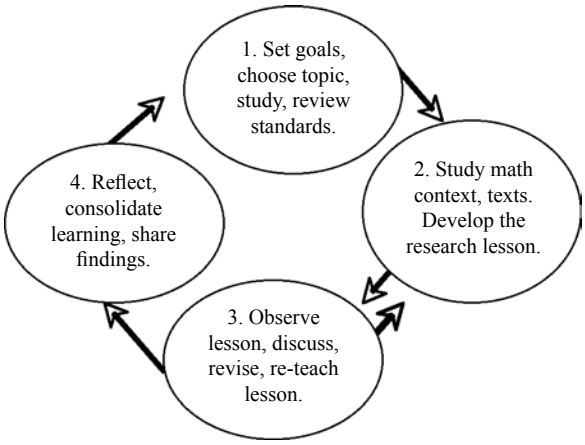
After being introduced through *The Teaching Gap* (Stigler & Hiebert, 1999) and the Third International Mathematics and Science Study (TIMMS), lesson study quickly gained attention in the U.S. as a promising strategy for creating long-term instructional improvement. The lesson study process that is emerging in the U.S. is a cyclical process, inspired by the Japanese model for lesson study. When participating in lesson study, small teams of teachers develop, test, and improve lessons for the purpose of building professional knowledge and improving the overall effectiveness of instruction. Teams of approximately 3-6 teachers meet regularly[1] over a one or two month period—including time for study, lesson development, team observation of the lesson with follow-up discussion, and reflection. The team's investigation of research lessons is an opportunity for teachers to open up a broad examination of mathematics, curriculum, teaching, and student learning.

In the National Science Foundation-funded *Lesson Study Communities in Secondary Mathematics* project[2], we have worked with dozens of schools and hundreds of teachers as they started lesson study in their schools. This work has shown us that lesson study provides many opportunities for teachers to deepen their understanding of and curiosity about mathematics, while also focusing on their students' learning of mathematics. Lewis, Perry, and Hurd (2004) argue that increased subject matter knowledge is one of seven



key pathways to instructional improvement that underlie successful lesson study. Increasing teachers' mathematical knowledge has been a key goal of our project's lesson study activities. However, we have observed that novice lesson study teams often struggle to understand the multiple goals and new skills involved in the lesson study process, and so may not fully capitalize on opportunities to build their own understanding of mathematics.

In our experience, a coach or facilitator can play a very important role in helping lesson study teams recognize and utilize the opportunities for teacher content learning that are embedded in the lesson study cycle. This leadership role might be played by an instructional coach, lead teacher,

[1] *Usually team meetings occur once a week and last for an hour or hour and a half, depending on the teachers' schedules. Meetings may occur during team time, common planning time, after school, or on professional development release time. The research lesson is taught during the regular school day, and teachers and administrators arrange for coverage or substitutes to observe it.*

[2] *This material is based upon work supported by the National Science Foundation under the Lesson Study Communities in Secondary Mathematics project, grant number ESI-0138814.*

department chair, mathematics coordinator, or university professor. These individuals may work alongside the team attending all their meetings, while others might consult regularly with the team at key points during the process. The leader can generally support teachers in maximizing their learning by guiding the team's progress through the cycle, asking key questions that help focus the work, and offering appropriate resources or expertise about the content. In our work with teams, we have identified some specific powerful strategies for focusing lesson study work around teacher and student learning of mathematics. Some are most appropriate at specific moments in the cycle, and usually become structured into the team's process at those points. Others are woven through the whole fabric of the lesson study cycle. Leaders can play a major role in helping teams incorporate these strategies into their regular lesson study practice. These strategies include:

- Doing mathematics together with colleagues
- Analyzing the development of mathematical ideas in your curriculum
- Examining the development of mathematical ideas across grades
- Sharing expertise on teaching the selected topic
- Anticipating student responses
- Observing student thinking about mathematics
- Focusing the post-lesson discussion on mathematical learning
- Bringing additional content expertise into the team's work

In this article, we describe each of these strategies in greater detail. First, we situate the strategy in the context of the lesson study cycle, then share examples of the strategy in action from our experiences working with lesson study teams, and lastly, we offer suggestions that may be helpful to leaders in supporting lesson study teams to implement that strategy. It is important to note that in our experience, teams may use different strategies at different times in their lesson study cycle, or may really emphasize one or two strategies (e.g., sharing expertise, analyzing the development of ideas across grades) in particular cycles of lesson study work together.

Doing Mathematics Together With Collegaues

Doing mathematics together with colleagues is a key strategy for enhancing teacher content knowledge in lesson study. A critical activity for *all* teams is to explore problems related to the team's chosen mathematics topic, at some point early in the lesson study cycle. Most commonly, after choosing a topic focus for their research lesson, all team members bring one or two problems related to the topic to share with their teammates. Teachers spend time working together on these problems in order to develop their own understanding of the mathematics and to identify challenging, appropriate problems for the research lesson. Sometimes, teams explore extensions of the problems or related problems from their textbooks because such problems are a more appropriate level of challenge for the teachers participating in the group, yet still offer insight into student thinking of that mathematics.

One middle school team that was focusing on linear equations (in particular the difference between equations of the form $y=kx$ and $y=kx+c$) worked together on the following problem.

- A BIG party is being planned and everyone will sit at hexagon-shaped tables. Many tables will be pushed together to make one long table. If 57 tables are pushed together how many people could sit at the table? Keep in mind that tables are joined at a side (edge) not at a vertex, and that only one person can be seated at a side (edge) of the hexagon.

- Find a way to accurately predict how many people could be seated, given any number of tables?

By working on the problem, team members discovered together quite a variety of rules that could express this relationship, discussed the difficulties students have understanding the difference between directly proportional relationships and those that are linear but not proportional, and generated and worked on a series of extension problems like "what happens if the shape is a pentagon?" "What happens if the tables can be joined in any way, not just in a line?" They also debated whether the y-intercept was meaningful in this context.

Many teams also establish habits of practice that involve doing mathematics together *throughout the cycle*. For example, one of the teams that we worked with in the *Lesson Study Communities in Secondary Mathematics* project decided to launch each of its regular lesson study meetings by working together on a mathematics problem. For each meeting, one teacher would be responsible for bringing a problem that related to the team's research

lesson topic and that would challenge the thinking of the team. As one teacher described it, "When we meet, one of the things that we like to do is to first individually solve a math problem and then share our strategies for solving it. ... Our variety of approaches has led us to think about all the strategies our students use."[3] Not all teams start every lesson study meeting with the exploration of a mathematics problem, but collaborative exploration of the mathematics through problems helps teachers to see how the key mathematical concept relates to the learning trajectory for a mathematical idea; to see connections across mathematical topics, and to see connections across grades, thus placing the topic in a broader mathematical context.

Suggestions for leaders: There are multiple opportunities within the lesson study cycle for teams to work on mathematics together. As a coach or facilitator, you might bring to the group engaging problems for the teachers to work on, or help them to create appropriate extensions to the problems from their textbook that they are exploring. By modeling and supporting this kind of exploration, you help teachers to build a connection between their own exploration of mathematics and their students' learning. Some guiding questions to keep in mind while teams are doing mathematics include: What is the important mathematics in this problem or these problems? What are we learning by working on problems together? What can help students learn that mathematics?

Analyzing the Development of Mathematical Ideas in Your Curriculum

In Japan, this analysis is called *kyozai-kenkyu*. We learned about this idea from Akihiko Takahashi, a leading expert on lesson study. *Kyozai-kenkyu* can be roughly translated as "instructional material research"[4] and in Japan is considered an important way for teachers to learn and improve their teaching. When a research lesson goes badly, the teachers may think "We need to do more *kyozai-kenkyu*." The idea is that teachers can learn by deciphering the curriculum writers' and other teachers' theories about how particular mathematical topics are developed. This idea grows from a belief that teachers can learn from and build upon high quality resources and research. Akihiko Takahashi describes the process as follows:

Kyozai-kenkyu[5]

A group of teachers usually does some ground work before actually developing a lesson plan. This investigation, called *"Kyozai-kenkyu"* in Japanese, includes studying:

- a variety of learning and teaching materials such as standards, textbooks, worksheets, and manipulatives
- a variety of teaching methods
- the process of student learning (students' typical ways of understanding, common misunderstandings and mistakes, etc.)
- research related to the topic

Teachers often begin *kyozai-kenkyu* by studying and comparing the teachers' guides published by various textbook companies.

One important aspect of curriculum analysis in lesson study is identifying the key mathematical goals of the lesson and unit. Lesson study teams need to ask themselves: What is it we really want students to learn or understand in this lesson and unit? What do students already know about the topic? What concepts are key to develop understanding? The focus of the curriculum analysis is on how students learn the content, and how the design of the lesson, unit, or chapter contributes to that student learning. If teachers work with high-quality instructional materials, this curriculum analysis strategy will help them to build on the best available lessons and knowledge for teaching the topic, thus allowing them to improve and learn from a quality lesson rather than trying to invent a brand-new lesson. Catherine Lewis (2002) has commented that "Lesson study is most productive when educators build on the best existing lessons or approaches, rather than reinventing the wheel […] Try to immerse yourself in others' lessons through whatever means you can…textbooks, research lessons, books, video […] If your group searches out and studies the best existing lessons, it will result in a better research lesson and help create a system that learns rather than one in which every group of educators reinvents the wheel." (p.62-63) One benefit of studying texts is that teachers become more aware of how well or poorly their textbooks and teachers editions are constructed to reflect a trajectory of learning.

[3] The quote here and the quotes on the pages that follow are from teachers who participated on lesson study teams in the Lesson Study Communities in Secondary Mathematics project.

[4] Definition from http://hrd.apecwiki.org/index.php/Glossary_of_Lesson_Study_Terms.

[5] The information about Kyozai-kenkyu shared here is from a presentation by Akihiko Takahashi in December, 2003 at a lesson study workshop for mathematics teachers hosted by Education Development Center, Inc.

Suggestions for leaders: For novice lesson study teams, we have found that the examination of teaching resources described above can be challenging because teachers are generally not accustomed to analyzing instructional materials in this way. As a coach or facilitator, you can provide support to teams as they begin to incorporate this strategy into their lesson study practice by offering good resources—particularly resources in which the intended trajectory of learning for students is clear—for teachers' examination. Sometimes, the study of national and state mathematics standards can be a valuable resource or entry point for investigating the development and connections between different mathematical ideas. You can also help in the analysis of these teaching resources by sharing your thinking about how the resource reflects particular ideas about student learning of the topic.

Examining the Development of Mathematical Ideas Across Grades: Vertical Integration Through Cross-Grade Teaming

Several of our lesson study teams found working on a cross-grade team to be particularly powerful in developing teachers' own mathematical knowledge, due to the diversity of mathematical experience in the group and the knowledge of the curriculum across grades. These teams consisted of grade six through eight teachers, or a mix of middle and high school teachers. We have also seen elementary cross-grade teams with two or three grades represented, and even one successful team that spanned grades K through 6. The expertise present in these groups enriched discussion of how particular mathematical ideas develop across the grades. Lesson study teams can consider questions such as: What mathematical ideas does this topic connect to in the previous grades? Where does this mathematical idea appear in the upper grades? What did students learn about this last year? Teams with experience at multiple grade levels will have a first-hand source of knowledge as they attempt to answer these questions.

One district's cross-grades team was comprised of middle and high school teachers and chose topics that were important at both levels, such as probability. They always spent time together learning about the topic by sharing and solving problems related to that topic from the different grade levels. Then the team developed two research lessons related to the topic, one appropriate for their middle school students and a second one appropriate for their high school students. Both the middle and high school teachers observed both lessons. This experience of working across grades gave the teachers greater insight into their students' mathematical thinking across a larger grade span, illuminated how the topic ideas emerge in the curriculum, and helped them streamline their curriculum scope and sequence.

Suggestions for leaders: Coaches and facilitators can help their teams to include an analysis of how a topic develops across grades as part of their work together. The team can be encouraged to seek input from teachers (or textbooks/standards) at other grade levels when the knowledge is not already represented by teachers on the team. Teams also study state and national standards to get a sense for how topics develop across grades, but a greater level of depth can be developed by sharing of teachers' first-hand knowledge on a cross-grades team. Some teachers are skeptical that a cross-grades team will work—concerned that studying a lesson outside one's teaching assignment would be uninteresting or not worthwhile. This skepticism usually fades quickly when the knowledge sharing in a cross-grades team begins.

Sharing Expertise on Teaching the Selected Topic

Lesson study is based on the fundamental idea that teachers are keepers and seekers of content and pedagogical expertise, and that by sharing it with one another, everyone gains. Hence, sharing expertise goes on throughout the cycle, addressing various goals. Early in the cycle, the team shares expertise as they select a lesson topic, discussing questions like: What topics are difficult for our students to learn? What are the important mathematical concepts we want our students to understand? During the process of developing the research lesson, teachers share expertise to identify the important mathematical ideas students may encounter in learning the topic. Questions such as the following drive the discussion: What does it mean to understand this topic? What are common student misconceptions? What are the important ideas that contribute to developing students' understanding of the topic? These discussions are often a very energizing experience for lesson study teams. Teachers share instructional approaches that they have found effective in teaching the topic, or places where students typically get stuck in learning about the topic. They may debate what prior knowledge is needed for students to understand a topic, or whether you can teach a concept even without all the ideal prerequisite skills in place.

For example, one team considering the broad topic of quadratic functions, learned through sharing their teaching experiences that a particular area of difficulty for their students was understanding the connections between solving equations by factoring, the quadratic formula, and zeros of the graph. This helped them narrow their focus for the research lesson.

Suggestions for leaders: One concrete way for a coach or facilitator to help lesson study teams focus on the mathematics through sharing of expertise is to make sure that formal time is set aside for this sharing. The team may benefit from time to write about what they know, or to talk about what they know, or some combination of these forms of communication. The coach or facilitator should consider the personal style of the team, as well as how the teachers on the team will be able to make sense of and use the knowledge that they share. Some important guiding questions include: What do we already know about effectively teaching the mathematics chosen for our research lesson? What has been difficult about teaching this topic? What are our open questions and what else do we want to know about the topic?

Anticipating Student Responses

Another key aspect of lesson study work is what teams usually call "anticipating student responses" to the problems or activities planned for the research lesson. The team will try to picture what methods students will use in solving problems as well as engagement and behavior. Anticipating students' responses can reveal predicted partial understandings, misconceptions, and a trajectory for student learning of a particular mathematical topic. Sometimes teachers find connections between their possible student responses and the methods they and their colleagues used to solve the same problems. Teachers can use their thinking about possible student responses to inform their lesson design by considering how to advance the thinking of students with particular responses and by increasing their own understanding of how students learn mathematical ideas. One teacher commented on her experience anticipating student responses: "It took us a while to make that leap into student learning. For a long time, we were still creating lessons…. Not just looking at student feedback, but analyzing student reactions made a big difference… I'd say I learned something about kids along the way, but I have a lot more to go….."

One elementary team worked on a problem for their research lesson that involved drawing on grid paper all rectangles that have whole number dimensions and an area of 24 square units, then making a table showing the rectangles' dimensions and perimeters as well as a graph of length and perimeter. When the teachers in this group had solved the problem themselves, they realized that different people computed the perimeters of the rectangles using different methods. They drew upon this experience to predict a number of different correct ways that their students might approach finding the perimeters for the different rectangles in this problem:

(1) Use values from the table to compute $2L + 2W = P$
(2) Look at each drawing and add the side lengths in order $[L + W + L + W = P]$
(3) Look at each drawing and add opposite sides then sum $[(L + L) + (W + W) = P]$
(4) Use values from table or drawings—add length and width then double $[(L + W) \times 2 = P]$

A next step for this team is to consider what incorrect or incomplete methods their students might employ. Making explicit possible *unexpected but desirable responses* from students can also help the team consider how they can develop students who are likely to extend their thinking in those directions. Another next step (and a critical one!) is to analyze each of the predicted responses, in order to determine what it reveals about student thinking about perimeter, and how the teacher can further the student's understanding from that starting point.

Suggestions for leaders: The team will focus intensively on anticipating student responses at a few key points in the process—generally after the lesson problems have been chosen and the team is refining their lesson plan pedagogy, and after the lesson has been taught as the team revises the lesson and considers what they have learned. You can help the team to consider the variety of ways that students might respond to the lesson problems, including correct, incorrect, and incomplete methods as well as questions or extensions to the problem that students might pursue. It is not enough for the team to stop at listing the solutions and solution methods they might see. To really explore the mathematics the team needs to take the next step of unpacking what these anticipated student responses might mean about how students are understanding the concept, and about how the

teacher can further that understanding. Remember, also, that the team will gain new insights about student methods when they observe the lesson. It matters more that the team keep attending to this than that they produce an impressive list at the first try.

Observing Student Thinking About Mathematics

The observation and discussion of a research lesson are central to the lesson study process. Observation of the lesson allows teachers to see first hand how students think about and learn the mathematical ideas in the lesson, what understandings students bring to the lesson, and what ideas students are struggling with. Having multiple observers enables the team to collect a great deal of detailed data about students, from different perspectives, thus creating a stronger basis for understanding and interpreting student thinking, and for evaluating the research lesson. This body of data also contributes to a richer discussion about the effectiveness of the lesson in promoting student thinking and learning. Teachers have reported on the power of watching one student or group through the whole lesson. This observation strategy allows the observer to see the students' full process (including wrong turns, down time, role in the group, etc.) and is a stark contrast to attempts to determine what students are thinking based only on the final solutions that they present or write. This is something teachers rarely, if ever, are able to do in their regular teaching.

The observation is also a reality check for the team. They may realize that there are areas of the mathematics that their students don't fully understand, or that their expectations of students' abilities or knowledge are unrealistic. What contributes greatly to the power of the observation is that the team has been fully immersed in the mathematics of the lesson and has formed hypotheses about how students learn this mathematics. This observation is a culminating moment in their research.

Suggestions for leaders: Observing student thinking with a researcher lens at the forefront rather than a teacher lens is one of the many "new" practices that teachers experience as part of lesson study, and therefore one that can benefit from the support of coaches or facilitators. You can help the team to determine particular questions to focus their observation, so that the team will be well equipped to collect useful data for the discussion after the lesson. You can also help the team to stay focused—the observation is about student learning of mathematics, not the teacher. Finally, share your excitement about the power of the observation with the team. The lesson study observation provides a unique opportunity for teachers to learn together about their research lesson, especially because the teachers planning the lesson don't know how it is going to go, and likely, the students will do or say things that surprise the team. Those moments of surprise are opportunities for understanding how students learn the mathematics, and you can help the team focus on those moments.

Focusing the Post-Lesson Discussion on Mathematical Learning

When the lesson is taught, a lot of observational data is usually collected. In order to provide focus when using those data, a key question to consider in the post-lesson discussion is: What did we learn about the mathematics and students' learning of the mathematics? The purpose of the post-lesson discussion is to share observations, discuss what those observations mean, and discuss what the team has learned from the teaching and observation of the research lesson. It can be helpful at the beginning of a post-lesson discussion, when everyone is eager to share what they have seen, to take a few minutes for some reflection on the key question, "What did we learn about the mathematics and students' learning of the mathematics?" A successful strategy we have used is to provide a prompt for a brief period of individual reflection and writing. Maintaining this focus on what is learned about the mathematics of the lesson makes it possible to have an evidence-based conversation, and ground interpretations and emerging theories in the collected data. The goal is to refine ideas about how students think about and understand the mathematics of the research lesson, which can then inform revision of the research lesson. Examples of questions that might be helpful to guide the discussion include: What was the effect of asking a particular question or posing a particular problem? What mathematics did students learn in this lesson or in a particular part of the lesson? What activities or questions helped to keep students' focus on the mathematics? When in the lesson did we observe the most student learning?

Suggestions for leaders: A coach or facilitator can play the role of moderating the post-lesson discussion, ensuring that the discussion stays focused on the data from the lesson about how students are understanding and learning the mathematics. Questions such as those described above can be helpful in this regard. The coach or facilitator will also have to attend to the particular needs of their group in order to determine the best way to keep a strong focus on the mathematics and students' learning in the post-lesson discussion.

One example of unpacking the mathematics in a post-lesson discussion comes from this entry in a log written by the coach for a lesson study team:

The teachers [on this lesson study team] have had trouble articulating what they think the math of their research lesson is, beyond stating the standards for probability or saying that the math is "understanding probability." During the teaching of the research lesson, students were able to correctly write some numbers in ratios but were having trouble connecting those ratios to verbal descriptions of the likelihood of particular outcomes. Teachers noted this trouble, so I asked them to try to describe what they thought students did and did not understand. The teachers responded that they thought the students understood the ratio of possible outcomes, but that they didn't completely understand what probability is because they couldn't connect it to those ratios. During the lesson, all of the small groups of students collected data and then pooled that data into one class set of data. The ratios for the class set of data were closer to the probability-driven predictions than the small-group data sets had been, but still did not match the probability-based prediction. (... Although the class data set drew upon data from several small groups, it still didn't include a very large number of trials). I asked how the results of the pooling of data might relate to the homework questions students would be answering that night about "why use probability?" I think in our next meeting I'll ask the teachers to predict possible answers that students might write for "why use probability?" as well as what answers they'd ultimately like to see from students, because it's a question we haven't explored as a group."

Leaders also need to keep in mind that the team will have two post-lesson discussions if the team is able to schedule time for revisions and a second teaching. In this case, there is a chance to revisit important discussion topics, or to focus more heavily on data relevant to revisions in the first discussion, and on larger mathematical themes in the second.

Bringing Additional Content Expertise Into the Team's Work

One of the lesson study teams with which we worked was participating in an NSF-funded Mathematics and Science Partnership program that brought together university mathematicians and study groups of secondary mathematics teachers. Because this school was already actively engaged in lesson study, the university mathematician joined the lesson study team. In one of their lesson study cycles, the teachers identified combinatorics as a topic that many of them were interested in learning more about for themselves, as well as for teaching their students. The university mathematics professor supported this team's learning by offering problems for the group to work on together and by making connections between different ideas such as combinations and permutations and how the formulas for combinations and permutations can be developed. This mathematics professor also participated in a lesson study open house[6] that the team hosted at their school, and following the observation and discussion of the research lesson, he led a session for the teachers who attended the open house to extend the mathematics from the student lesson. This idea of drawing on a content expert, sometimes referred to as a "knowledgeable other," is common in the Japanese practice of lesson study.

Suggestions for leaders: Often, the coach or facilitator is a source of outside expertise for the team—sometimes bringing knowledge of the lesson study process, or group facilitation, or of the mathematics and pedagogy. It is important that the coach or facilitator help the team determine what needs they have for expertise beyond what is represented on the team, and how they might access that kind of outside expertise. Outside expertise often comes in the form of invited guests to participate in certain parts of the lesson study process, in particular the study of the content or the lesson observation and post-lesson discussion. However, content expertise can also be brought to the team in written form, by finding articles and books about relevant research. Inviting in outside experts also brings some challenges in that the teachers may have a difficult time relating the outside expertise to their work, or may feel inadequate in their own knowledge or understanding. An important role for a coach or facilitator is to familiarize the visitor with the goals of the lesson study process, and work to help teachers think about how best to incorporate this new knowledge or perspective into their current thinking.

[6] *A lesson study open house is a form of professional sharing and learning during which a lesson study team invites outside visitors to observe the teaching of their research lesson and participate in the post-lesson discussion based on that research lesson observation.*

Conclusion

All of the strategies described here are an integral part of the lesson study cycle, but in practice, there is often quite a bit of variation in how lesson study is implemented and in some cases, key elements of the lesson study process are missed or addressed quickly or superficially. Within the lesson study process, there are plentiful opportunities for teacher learning of mathematics. However, it can be challenging for teams to take advantage of these opportunities, especially new teams, because they can be overwhelmed with learning all the parts of the lesson study cycle, or are focused primarily on developing their lesson. They may also be unaccustomed to learning mathematics in the ways offered by lesson study because teachers do not usually have the time to examine the mathematics and their teaching practice in the ways the lesson study process allows. However, we have seen in our work that once introduced to these strategies, teachers welcome and embrace the kinds of opportunities available through lesson study to develop their own understanding of mathematics.

As we mentioned above, we have found in our work that a coach or facilitator can be tremendously helpful to lesson study teams by leveraging opportunities for mathematics learning in the process. An important leadership role for coaches or facilitators is to help the team recognize the opportunities for their own learning of mathematics embedded in the lesson study cycle. In addition, mathematics leaders can think strategically about the fit between the various strategies described in this article and the needs and contexts of the team of teachers with whom they're working. A mathematical leader can also model good mathematical discussions and ask thought-provoking questions at critical junctures. Similarly, a coach or facilitator can support individual teachers on lesson study teams as they take on responsibility for attending to mathematics learning, and eventually, over time, these strategies can become core elements of the teams' lesson study practice. Helping the team see why mathematical explorations are important, and the connection between learning the mathematics for themselves and the improvement of their teaching and their students' learning is a critical contribution that a coach or leader can make in their work with a lesson team.

We close by offering a number of reflection questions for coaches and leaders engaged in assisting teams to keep the learning of mathematics central in their lesson study work.

- Are teams having substantive discussions about mathematics? How does the content teachers are exploring extend their own understanding? How does it help them better understand students' thinking about the mathematics?
- What evidence is there of a strong focus on mathematical thinking and on how mathematical ideas develop in the team's work?
- Does the team bring a learning stance to their lesson study work? How open are teachers to developing new understandings of the mathematics and their students' learning?
- What connection do teachers see between their own understanding and learning of mathematics and their students' understanding of mathematics?
- Are teachers on the team posing questions about mathematics and their students' learning of mathematics that they are interested in exploring?

In addition, there are some resources available to assist leaders who are working with teachers using the lesson study process. A few of these resources include:

- Lesson Study Group at Mills College, *www.lessonresearch.net*. This group offers resources for new lesson study teams and maintains a library of articles and research related to lesson study. They have developed research-based toolkits for proportional reasoning, area of polygons, and fractions that enable mathematics lesson study groups to access and use content knowledge effectively.
- EDC Lesson Study Center, *www.edc.org/lessonstudy*. This group is developing a ten-session professional development course for teams new to lesson study in mathematics, and a leadership guide for coaches, facilitators, and other leaders. These materials will be published by Heinemann and available in 2010. The group also offers services in support of lesson study implementation, research, and lesson study in mathematics workshops. The website also includes information about the *Lesson Study Communities in Secondary Mathematics* Project.
- Global Education Resources, *www.globaledresources.com*. GER provides materials, workshops, and services to teachers, schools, and districts. Resources include English translations of widely used Japanese mathematics textbooks for grades 1–6.

We encourage you to try some of the strategies and guiding questions described in this paper, and access the resources listed above as you work to improve mathematics teaching and learning through lesson study in your own school or district.

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