The value of collaboration and reflection with peers to improving instructional practices is well known (e.g., Lieberman 1992; Little 1982; Little and McLaughlin 1993; Romberg 1988). However, practicing mathematics teachers are often challenged to find time in their busy schedules to collaborate with peers. Recently, during the implementation of a lesson study experience with a small group of preservice secondary mathematics teachers, we observed firsthand how lesson study could be used to encourage collaborative reflection among preservice teaching peers and how it potentially could be used to support ongoing professional development of in-service teachers while respecting their time constraints.

Lesson study is a teacher-directed program for improving instruction. It focuses on improving students’ learning by systematically refining the lessons used for instruction. Teachers involved in lesson study meet regularly to plan, implement, test, and revise lessons, sometimes according to a theme or focus previously agreed on but always with the intent to improve students’ learning (Curcio 2002a; Fernandez and Yoshida 2004; Lewis 2002; Stigler and Hiebert 2000). The lesson study cycle typically involves the following steps:
• Teachers form a planning team and define a problem for investigation, often involving a challenging content area for their students.
• Teachers design a lesson to address the problematic area.
• One teacher from the planning team teaches the lesson, while the other teachers observe as it is taught.
• The observers notice whether students seem to understand (or not understand) the lesson.
• Following the lesson, the teachers meet in a debriefing session to analyze the lesson’s strengths and weaknesses from the perspective of the students’ learning.
• The lesson is revised on the basis of the observed needs of the students.
• The revised lesson is then taught to a second group of students.

The cycle of planning, teaching, assessing, and revising lessons continues for as long as the teachers feel that the lesson can be improved. They collaborate in the process. Although their teaching is observed, they feel less pressure than when being observed for the purpose of evaluation. Lesson study can have immediate classroom impact. Through ongoing involvement in the process, teachers can learn to collaborate and reflect effectively with peers, not only to improve daily lessons but also to confront larger social or cultural problems within the school.

In this article, we describe the introduction to lesson study that we implemented with preservice secondary mathematics teachers. The experience occurred with ninth graders in two geometry classrooms during regular school hours. With a few adaptations, lesson study could be implemented by in-service teachers without requiring a large investment of time beyond the regular school day.

PREPARING FOR LESSON STUDY
We introduced lesson study and observed how it might encourage collaborative reflection when eight of our preservice secondary mathematics teachers were simultaneously placed at one large suburban high school for their clinical experience. We prepared a survey on attitudes and beliefs about preparation and classroom focus for teaching to measure changes in their views of the value of collaboration, and, during one of the regular methods class meetings, we gave an overview of the steps involved in lesson study. The preservice teachers viewed a video showing a lesson study in progress (NCREL 2002) and were encouraged to think about and ask questions about how lesson study could be used in their clinical setting. Later they read and discussed an article about the implementation of lesson study and its value to improving classroom instruction (e.g., Stepanek 2001). The most effective part of this introduction was the preservice teachers’ opportunity to see the lesson study process by video. This kind of preparation could be recreated for in-service teachers by using lesson study videos (those we have noted or others) or by observing a lesson study session in another school.

The preservice teachers’ questions included these: “What is lesson study meant to accomplish?” and “Is it more effective than individual lesson development?” The preservice teachers thought the lesson study process “makes the lesson and learning much more effective” and “is a great way to make sure that you use fresh new ideas”; further, “rather than [only] examining student work, teachers should be examining students working.” Although insights into the effectiveness of lesson study accrue from direct involvement, familiarization meetings such as these for either preservice or in-service teachers can clarify the steps of the process, the roles of those involved, and expectations from involvement in the process.

After the familiarization meetings, the preservice teachers began to consider lesson topics. They decided that the lesson would center on helping students link previously learned right-triangle procedures to an area-based concept of the Pythagorean relationship. They planned details of the lesson over several class sessions, despite the sometimes cumbersome group size of eight individuals. For in-service teachers’ first attempt at lesson study, groups of four or five teachers, meeting several times after school for one to two hours, may be preferable.

Ideally, instruction focuses on concepts before procedures. Even with ideal instruction, however, some students may not fully connect procedures and concepts unless given multiple opportunities for those connections to develop. The preservice teachers knew that the students with whom they would be working had already learned the Pythagorean theorem as \(a^2 + b^2 = c^2\); they also recognized the possibility that the students may have memorized this formula without understanding it. Wanting to focus on underlying Pythagorean theorem concepts, they decided that the lesson’s objective would be for students to understand how the areas of the squares on the legs of a right triangle could be combined to equal the area of the square on the hypotenuse.

Finalizing the lesson involved the give-and-take of open discussion. The preservice teachers sat with their desks arranged in a circle and freely exchanged ideas as they considered many approaches for engaging the students.
ideas as they considered many approaches for engaging the students. Some suggestions included opening the lesson with a brief biographical sketch of Pythagoras and connecting the theorem to the distance formula or to the real-world context of a baseball diamond. The preservice teachers also considered technical matters such as the arrangement of desks in the classroom and the timing of the lesson’s various parts. They discussed whether to use a dynamic power point demonstration or paper cutouts to illustrate the Pythagorean relationship and how to handle practice problems, and they worried about the classroom observers causing disruption of learning. Viewing a second video on the practical implementation of lesson study (Curcio 2002b) somewhat allayed their concerns.

In the end, the students agreed that they would follow this sequence of steps for the lesson:

1. Introduce the lesson by giving a biographical sketch of the Pythagoreans.
2. Ask students to recall what they know about the Pythagorean theorem.
3. Present a dynamic Web-based video clip of how the areas of the regions of squares on the legs can be reassembled into the square region on the hypotenuse (www.usna.edu/MathDept/mdm/pyth.html) (see fig. 1 for an illustration representing this concept).
4. Have students use paper cutouts to demonstrate how the regions of the squares on the legs can be combined and reassembled to equal the cutout region of the square on the hypotenuse.
5. Have students complete numeric exercises by using the Pythagorean theorem.
6. Have students complete an “exit slip,” in which they briefly describe what they learned from the lesson.

The details of implementing the lesson study were arranged by the methods course instructor. She described lesson study to the classroom teachers and encouraged their support for the preservice teachers. Two classes were selected for implementation on the basis of course content and meeting times. The original lesson was taught in a morning class, while the revised lesson was taught in the afternoon of the same day. This schedule allowed ample time for the debriefing session to be held between the two classes’ meeting times. The preservice teachers who had been working with these classes agreed to teach the lessons. One taught the lesson as it was initially planned, and the other taught the revised lesson after the group’s analysis of the first presentation.

TEACHING, OBSERVING, AND ANALYZING THE LESSON

On the day the lesson was taught, the preservice teachers, the regular classroom teacher, the mathematics department chair, and two teacher educators were present, accounting for a total of nine extra people in the room. The classroom students, who had been told the previous day that there would be observers in the room, largely ignored the extra people. The class’s preservice teacher started the lesson by asking students to recall their knowledge of right triangles, including the hypotenuse and legs of a right triangle. The classroom observers began to look for aspects of the lesson that students grasped or did not grasp; as suggested by lesson study practitioners, they did not interact directly with either the teacher or the students (Curcio 2002b).

Then the preservice teacher sketched a right triangle on the board, drew squares on each of the sides, and asked whether the squares on the legs could be “put into” the square on the hypotenuse (see fig. 2). Several students did not immediately connect their previously learned knowledge of the Pythagorean theorem with the question. The preservice teacher distributed packets containing the cutouts and asked students, first, to construct a picture with the square regions appearing on the legs of the triangles and, later, to reassemble the pieces from the squares on the legs into the square on the hypotenuse. Later he added a few biographical remarks about Pythagoras and showed the video clip of the cutouts from the squares on the legs being reassembled into the square on the hypotenuse. To close the lesson, students completed several numeric examples in which either the hypotenuse or one of the legs was unknown. Then they wrote a short statement (exit slip) about what they had learned (the preservice teacher asked specifically for something more than “$a^2 + b^2 = c^2$” as an answer).

After the lesson, the preservice teachers and teacher educators met in an empty classroom to
discuss and analyze the lesson. This debriefing followed lesson study protocol in that the lesson teacher was the first to report his impressions (Curcio 2002b; Fernandez and Yoshida 2004; Lewis 2002; Stigler and Hiebert 2000). Then the observers took turns, first thanking their preservice colleague for teaching the lesson and then sharing their comments on the lesson’s strengths and weaknesses as it had been implemented and of students’ understandings and misconceptions of the lesson objectives. The teacher educators shared their final observations. The lesson teacher was generally pleased with having covered all the planned parts of the lesson but was uncomfortable with the timing of various parts and with having forgotten to present the biographical sketch of Pythagoras at the beginning. Several observers remarked that mixing up these parts of the planned sequence had little effect on the lesson’s success.

In analyzing the lesson, the preservice teachers asked, “Did the dynamic video clip assist the students in making the desired connection?” “How did the students interact with the teacher?” “Was the teacher’s instruction direct or inquiry-based?” “Were students able to apply their knowledge?” “What did the students learn?” and “What did the exit slips indicate?” The observers noticed that most students grasped the area relationship of squares on the sides of the right triangle (see fig. 3). During the lesson presentation, the preservice teacher reversed steps three and four of the lesson sequence to have the students explore with the cutouts before viewing the video. During the follow-up discussions, none of the preservice observers nor the teacher himself remarked on this change, which may have engaged the students more fully in problem solving and reasoning about the Pythagorean relationship than the lesson as originally planned. The preservice teachers evidently intended the sequence as implemented because they repeated that ordering of these steps in the second teaching.

The discussion focused on how well students were grasping concepts. Most of the lesson improvements were suggested by the preservice teachers rather than the teacher educators. Many suggestions focused on actions that the preservice teacher could take to make procedures with the Pythagorean theorem clearer. For example, the preservice teachers suggested, “Try not to erase the pictures you draw at the board too fast, as some students were struggling to identify legs and hypotenuse,” “Show all steps when solving a numeric example,” and “Keep the labeling of sides uniform (e.g., do not identify $c^2$ as hypotenuse² or as $?$²).” But other comments focused on how to assist students in grasping the concept of the area model of the Pythagorean relationship. A preservice teacher
suggested, “Give more assistance for reassembling the cutout pieces into the square on the hypotenuse.” A mathematics educator added, “Be careful not to ‘give away’ the relationship, as it is to be discovered.” And another preservice teacher suggested, “Ask, ‘How does $a^2 + b^2$ compare to $c^2$?’ and allow the students time to answer.”

Regarding students’ work, one preservice teacher noticed that students’ drawings “were not always accurate.” Another remarked, “It’s okay to let [students] struggle. They have to think about it” and “The video clip helped. Maybe play it twice.” In their exit slips, very few students mentioned that the Pythagorean theorem applies only to right triangles.

Collaboratively, the preservice teachers decided to make several changes to improve the lesson. They agreed to give the Pythagoras biographical sketch at the start of the lesson as originally planned and close the lesson by summarizing major points. They also decided to keep the labeling of the sides of the triangle examples consistent to facilitate students’ comprehension and also to give some nonright triangle examples to “test” students’ understanding. They also enlarged the image of the video clip for easier viewing.

THE CYCLE REPEATS

The second presentation of the lesson, given to the afternoon class, encouraged students to reason about when and how the Pythagorean theorem can be used. That class’s preservice teacher emphasized that the theorem applies only to right triangles and then posed the question, “Do you know why it works?” Receiving no response, he distributed the cutouts and asked students to try to put the pieces from the squares on the legs of the triangle into the square on the hypotenuse. Following the students’ explorations, he presented the video and encouraged students to explain the Pythagorean relationship. Then the preservice teacher drew an example on the board that was not a right triangle. He labeled the shorter sides of the triangle 6 and 7 units, respectively. When he asked the students, “Do this one,” they recognized that the triangle was not a right triangle and shouted, “You can’t!”

The preservice teacher’s decision to pose a question involving a nonexample shows how quickly and effectively he was able to take suggestions from the debriefing and make adaptations that challenged students’ thinking.

In the follow-up discussion, the preservice teacher noted a problem typically encountered by inexperienced teachers: He ran out of exercises for students to work on at the end of class time, and they lost focus. The observing preservice teachers did not address this concern but concentrated on students’ understanding of concepts related to the Pythagorean theorem. One student suggested, “Give the students more time with the cutout pieces. Let them figure it out. Don’t tell them right away how certain pieces should be positioned.” Others remarked, “The kids did good [sic] with the nonexample,” “Ask, ‘In what situations would you use the Pythagorean formula?’” and “The concept [understanding] was met with the video and manipulatives.” Still other comments reflect the preservice teachers’ own deeper awareness of the mathematics within the Pythagorean theorem: “The model shows why you have to take the square root. We’re using areas, and square roots give the distances back” and “The objective was to connect the formula knowledge to the concrete model. [The cutouts] gave something different to work with than just square roots.” The preservice teachers made one surprising observation: Although the students recognized during the lesson that the Pythagorean theorem applies to right triangles only, their exit slips indicated no better performance in remembering to stipulate this condition than did the exit slips of the students who were taught the first lesson.

ENGAGING IN COLLABORATIVE REFLECTION

Comments made in the debriefing sessions suggest the power of lesson study to engage preservice teachers in collaborative reflection. We expect similar findings with in-service teachers involved in lesson study. The effectiveness of the lesson study approach is likely due to several factors. First, as a lesson development tool, the process can systematically improve the quality of classroom instruction. Second, the process ensures that teachers receive timely and relevant feedback about their instruction and allows a quick opportunity to plan and implement revisions. Third, the common goal of lesson study participants—to improve learning—removes the fear of personal evaluation from any single teacher. Fourth, and perhaps most important, the full engagement of both in-service and preservice teachers in planning and implementing a lesson, observing students’ learning, assessing lesson effectiveness, and revising lessons according to students’ needs allows teachers to form a team through which their professional knowledge and efforts are recognized and valued by peers. Once established, the team can collectively address broader social or cultural based problems within the school.

On the survey of attitudes and beliefs about preparation and classroom focus for teaching given before and after the lesson study experience, the preservice teachers responded to two questions in which they ranked several possible teacher actions to address a problematic instructional situation. While their responses to one question were largely
unchanged, their responses to the other—describing students’ struggle to grasp concepts about the solution to systems of simultaneous equations—did change. On this question, the response options ranged from choices involving consultation with other teachers (e.g., discussing the situation with a fellow teacher and revising the lesson plan according to the suggestions given) to choices involving no interaction with other professionals (e.g., checking the teachers’ manual to be sure the necessary mathematics has been covered). After the preservice teachers’ participation in the lesson study experience, their responses to this question showed greater consideration of collaboration as an option for improving teaching and learning. They indicated that they would be more likely to seek the advice of a colleague about handling the situation or even requesting peer observation in the classroom. These responses suggest that the preservice teachers valued the collaboration from their lesson study experience.

In later discussions, however, we learned that the preservice teachers might hesitate to undertake such collaboration with their cooperating teachers for fear that their requests for collaboration would be an inconvenience for the other teachers. Lesson study groups for in-service teachers could provide an organizational structure through which any teacher could seek input regarding a challenging teaching situation and not worry about inconveniencing other teachers.

CONCLUSIONS AND IMPLICATIONS
Lesson study can become a supportive framework for the reflective collaboration of teachers as they strive to improve instruction. Beginning teachers often focus on technical aspects of implementing their lessons and overlook the effect of their instruction on learning (Goldsmith and Shifter 1997). Through their lesson study experience, our preservice teachers were able to observe students’ responses to instruction, focus on student learning, and revise a lesson accordingly. Experienced teachers, too, can grow professionally from lesson study. Their involvement will enable them to reflect on their own practices and foster teacher collaboration while providing support for beginning teachers.

REFERENCES

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