A CASE STUDY OF LESSON STUDY IN A HIGH SCHOOL: IMPLEMENTATION AFTER THE INITIAL FUNDING CEASE

BY

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DISSERTATION

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Abstract

This study examined the implementation of lesson study as a method of professional development in a high school setting after the initial funding had ceased. The participants had had experience with lesson study and included three math teachers, two science teachers, one special education teacher who collaborated with the science teachers, one literacy coach, and one curriculum coordinator. Data collection included secondary sources obtained by the university partnership; observations of the lesson study, the participants' regular classrooms, and department meetings; two phases of in-depth interviews; an open-ended survey; and artifacts of the process of lesson study. The implementation of lesson study after the end of funding with support from a facilitator did yield some benefits for the participants, although they also confronted several challenges, such as time, scheduling, and various levels of understanding of what lesson study is. After implementing the lesson study, participants demonstrated changes in instruction, concern about student needs and performance, and collaboration with colleagues. Also, similarities between the regular department meetings and the lesson study meetings were found, which might contribute to the successful adaptation of lesson study into the U.S. context. Fully informing teachers about lesson study and giving them practical experience with it as a method of professional development can lead to its continuity.

To My Mother Duck Im Park

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Chapter 1

Introduction

Background

Most professional development programs are funded. Therefore, once the funding ceases, the professional development program cannot continue no matter how beneficial it was for teachers. This phenomenon has led educators to consider how to maintain high-quality programs for teachers without a concern for funding. However, there is still a lack of research on what happens after the initial funding ceases. This study shows what really happens when the funding ceases, which might reveal ways to construct a professional development program that can continue for a long time without funding.

This study focused on a detailed description of the implementation of lesson study as a professional development program at a unique high school setting by volunteer participants without funding. The participants had previously experienced a funded lesson study and faced complex issues such as test pressure, new curricula, and new technologies for teaching and learning.

Since case study allows deeper interpretations and explanations of the complexity of a unique case (Stake, 1995), this study was implemented as a case study for shedding light on this implementation of lesson study. Interviews, participant and non-participant observations, open ended surveys, and detailed field notes were the main tools of data collection. Relevant artifacts were also collected as necessary. The intent of this study was to support lesson study as a method of professional development for high school teachers, which would affect teacher practice. More details on the methodology will follow in Chapter III. While the focus of attention in this

dissertation is on lesson study done after funded work was complete, it is important to understand the prior experiences some of the participating teachers had with the process.

Overview of previous funded lesson study. A three year long university partnership with funding had been implemented from 2005 to 2008 at the high school where this study was conducted. The ultimate goal of the project was to help teachers improve the quality of their instruction and thereby improve student achievement in mathematics and science. Improved instruction included student-centered classroom activities related to problem-solving skills, strategies for integrating mathematics and science, and the creative usage of technology in teaching.

The project had three goals for the partnering school districts:

1.1 To develop content-based, technology-rich professional development opportunities for mathematics and science teachers

1.2 To help create a supportive climate in the participating schools for sustained professional development opportunities for teachers

1.3 To help improve student achievement in mathematics and science by enhancing teachers' content and pedagogical knowledge and skills. (Travers, Gregson, Kim, & Lim, 2008a, p. 11)

The executive summaries of each year from the project were reviewed in order to obtain general information about the project and how it was implemented.

Year 1. The goal of the project was to create and implement professional development programs for teachers. For the 2005 summer workshop, 22 teachers attended the high school sessions. Numerous follow up sessions throughout the school year were held to strengthen and enhance the summer workshop goals. "Impact surveys" of the teachers showed how the project influenced teachers' instructional practices. Quantitative and qualitative data such as surveys,

interviews, and observations were collected and analyzed to discover whether this project impacted teachers' instruction (Travers et al., 2008a, p. 2).

The participants were introduced to action research as a method of helping them become more thoughtful about their teaching. Action research assisted them in reflecting on their instruction based on their interests in their math and science classes. As a result, teachers were able to provide reflections on their teaching and on student learning. Also, students became more comfortable with using technology through their instruction (Travers et al., 2008a, p. 17).

Participants were more interconnected, but less proactive at attending ongoing professional development programs. Surprisingly, their administration offered dedicated support for the project. Hence, this high school provided an outstanding opportunity for examining the effects of lesson study and continued administrative support "on the long term sustainability and effectiveness of teacher professional development programs" (Travers et al., 2008a, p. 18).

The report from Year 1 informed the development of Year 2, especially the summer 2006 workshops, including subject matter and workshop length. Thus an experiment model was used for Year 2 at the high school, "in which the summer workshop was one week, with the remaining five days distributed throughout the following school year" (Travers et al., 2008a, p. 57). The project facilitators noted that lesson study was a useful method for encouraging professional development, because it was a classroom-focused approach that allowed teachers greater benefits than the action research method in terms of active reflection and collaboration with peers. Lesson study is similar to action research in helping them reflect on their teaching. As a result, lesson study replaced action research in Year 2 of the project (Travers et al., 2008a, p. 57).

Year 2. During the summer of 2006, a one-week trial summer session with 27 teachers was held at the high school, with periodic follow up sessions during the 2006-07 school year to

support teachers. As in the previous year, "impact surveys" were collected to show the impact of the project. Furthermore, a Survey of the Enacted Curriculum (SEC) was given to teachers both in May 2006 and in May 2007 in order to identify possible benefits of the project on their teaching (Travers, Gregson, Kim, & Lim, 2008b, p. 3).

The findings of Year 2 illustrated that teachers obtained more specific content knowledge related to their subject areas, awareness of intended goals of the project, familiarity with the activities of the workshops, and details of early implementation of the project activities. This is encouraging to facilitators, because it indicates that the project did enhance the teachers' pedagogical and content knowledge, with the anticipation that this would lead to improvement in student achievement in mathematics and science (Travers et al., 2008b, p. 22).

Although teachers indicated some positive outcomes from action research on their reflective practices, facilitators noticed that introducing educational research to teachers and helping them become practitioners is a complex process. Teachers often failed "to see the direct relevance of research to their day-to-day activities" (Travers et al., 2008b, p. 20). Therefore facilitators turned to lesson study in the hope that it would lead to more practical and productive outcomes for the teachers (Travers et al., 2008b, p. 20).

Compared to Year 1, Year 2 saw the participation of more experts, including professors of diverse branches of mathematics, science, engineering and technology. These experts provided participants with practical information about content knowledge, current trends in education, and new technology for the classroom (Travers et al., 2008b, p. 82).

Year 3. As in Year 2, 22 teachers participated in the one-week workshop at the high school in the summer of 2007. Follow-up sessions were held during the 2007-08 school year, and "impact surveys" and SECs were collected to show the teachers' improvement in their teaching.

The summer workshop emphasized the enhancement of teachers' content knowledge of mathematics and science. In addition, it focused on helping them guide their students' achievement through technology-based instructional strategies (Travers, Gregson, Kim, & Lim, 2008c, p. 3).

The summer workshop was held over the course of five days. Based on participant request, follow-up sessions were held during the school year. These consisted of various breakout sessions organized according to the needs of the participants, by grade or by course (i.e. algebra, geometry, physics, etc.). Sometimes they worked individually on their own areas of interest, and other times they worked in small groups. Overall, they collaborated during breakout sessions and agreed to continue with lesson study throughout the school year. The breakout sessions were "specifically devoted to assessment of curriculum implemented in 2007-2007 (e.g. *Discovering Algebra*, *Discovering Geometry* etc.) and to preliminary planning for Lesson Study" (Travers et al., 2008c, p. 19).

Fernandez (2005) emphasizes that lesson study provides opportunities for teachers to discuss content and instruction in an organized way. It also enables them to reflect on their teaching and their students in the context of a collaborative environment (Takahashi & Yoshida, 2004). Thus, recent research on lesson study and positive feedback about lesson study from Year 2 encouraged facilitators and participants to continue lesson study into Year 3 in order to understand how to collaborate and teach mathematics and science with improved strategies (Travers et al., 2008c, p. 62).

Most participants reported that the three year project had changed their teaching and/or curricula to improve student achievement. Also, they shifted their subject matter emphasis based on student learning as a result of their participation in the project. Their self-reports indicated

that they had become confident at teaching problem-solving in their subject areas. In fact, science teachers conducted studies of how students learn particular topics in science more often (Travers et al., 2008c, p. 75).

Summary of funded lesson study implementation. This lesson study consisted of two different groups with slightly different contexts: a math group and a science group.

Math group. The math group consisted of six high school math teachers and their curriculum coordinator, and they implemented lesson study as a big group in Year 2 with the help of three facilitators and a mathematician, who joined the group in order to assist with conducting lesson study in a high school mathematics context. "Linear equations" was chosen as the unit for lesson study and "Knot tying" was selected for the research lesson topic. The math group investigated "whether students were able to find an equation that fits a real-world set of data, and use a mathematical model to make predictions" (Travers et al., 2008b, p. 58). Two teachers in the group delivered the research lesson, and the whole group observed the lesson deliveries. They debriefed about what they had observed and learned after each teaching. The group modified the lesson plan based on the debriefing for improved teaching and learning of mathematics (Travers et al., 2008b, p. 58).

Participants acquired some benefits from the lesson study activities. First, they gained content knowledge about mathematics and science through discussing and sharing with other teachers. They became aware of what they must teach in order for student to learn mathematic concepts efficiently. Second, they constructed a learning community in the same building, so they were able to collaborate and cooperate for continuous professional development. Lastly, they may have achieved a better awareness of how students learn mathematic concepts based on their observations of students. They also discussed details of lesson plans to improve student

achievement. Generally, lesson study provided the teachers with profound insights into teaching and learning via a different approach (Travers et al., 2008b, p. 59).

Nonetheless, participants at first faced several limitations and challenges with putting lesson study into practice. First, they needed a clearer understanding of what lesson study was. For instance, some of the teachers interacted with students when they were observing the delivery of the research lesson, which they were not supposed to do. Second, they had a time management problem: they needed more time for planning the research lesson and debriefing. Finally, they needed to be more flexible about collaborating and sharing ideas about teaching and learning. They needed to regard the observations of others as sharing instead of evaluating, so they would be able to comment freely about what they had observed (Travers et al., 2008b, p. 59).

Having implemented lesson study as a large group in Year 2, the math teachers decided that it would be more effective to break into two groups for Year 3: algebra and geometry. The planning time included "defining broad goals and setting an initial schedule" (Travers et al., 2008c, p. 19). They defined specific objectives for the research lesson during the second planning sessions. The broad goals for the math and science groups were:

1. To help themselves become more comfortable with using technology for teaching
2. To increase and improve their use of technology in the classroom
3. To help themselves better understand student learning processes
4. To improve student ability to use technology
5. To improve student achievement with the help of technology (Travers et al., 2008c, p. 20)

Through this second attempt at lesson study, participants learned how to design lessons effectively concerning the use of technology and student learning. Lesson study especially helped the algebra group discuss issues with adapting the new textbook and find solutions based on discussion. Moreover, they were able to enhance their content knowledge and instructional knowledge (Travers et al., 2008c, p. 62).

Science group. Year 2 was the first time participants had been introduced to the idea of lesson study. During the summer workshop they showed their willingness and enthusiasm to expand their insights about students' understanding of scientific concepts, and they expected to learn many things from lesson study by observing other classrooms, communicating with peers, and looking closely at student behavior (Travers et al., 2008b, p. 59).

Despite these positive expectations, it was not easy for them to implement lesson study for the first time. They had a hard time fully understanding what lesson study was and what they were supposed to do. For instance, when they observed the classroom where the research lesson was delivered, some of the observers tried to interact with the students, which they were naturally inclined to do as teachers. However, they were not supposed to do so because the purpose of observation was to observe students coming to understand scientific concepts as they interacted with only one teacher. Any extra help would not represent a natural classroom (Travers et al., 2008b, p. 59).

During the debriefing, all participants expressed their struggles with teaching science. One teacher who delivered the research lesson stated that the science department really needed at least one science laboratory in which students could do experiments. He was concerned about the time consumed setting up and cleaning up all the equipment in a regular classroom. Other

teachers said they benefited from observing other classrooms, obtaining different instructional strategies from peers, and sharing teaching ideas (Travers et al., 2008b, p. 59).

It was observed that the science teachers had some challenges teaching science because they were unsure whether to teach the scientific concepts or the procedures of the experiments when they planned and delivered the research lesson. Also, they did not seem to be engaged in lesson study as a method of professional development. They had not yet reached the point where they had improved their teaching via lesson study (Travers et al., 2008b, p. 59).

Since Year 3 was the science teachers' second attempt at lesson study, the expectation was that they would have a deeper understanding of the lesson study process, a more positive attitude toward lesson study, and a willingness to improve their instructional knowledge based on lesson study. Seven teachers had two discussion times each with me to outline an implementation of lesson study during the summer workshop. They needed more clarification about the lesson study process and determined the time when they would deliver the research lesson and debriefing. They chose "conceptual physics" as their subject and selected Excel computer software as the technology to use. They were concerned about the time consumed making a detailed research lesson plan script and the amount of work for all of the procedures of a formal lesson study (Travers et al., 2008c, p. 62).

They decided not to have a script for the research lesson due to lack of time and the decision that it was not necessary. One teacher delivered the research lesson about graphing with the Excel program in the science computer lab, and the rest of the team and facilitators observed the class without interacting with the students. We focused on different groups in order to discuss various observations later. The teacher had problems showing all the students how to log on, but

she figured it out with the help of a technician. During the debriefing, some teachers suggested a better way to solve the logon problem next time (Travers et al., 2008c, p. 63).

The second delivery of the research lesson showed improved instructional strategies and interaction with students. The teacher seemed to be confident about what he was doing. Students showed a better understanding of graphing than they had in the previous classroom session. During the second debriefing teachers mentioned how lesson study had expanded their perspectives on students, encouraged closer investigation of activities, yielded more flexible responses to individual students, increased communication with other teachers, and led to more thought about students' understanding of scientific concepts (Travers et al., 2008c, p. 64).

> T1: Comparing two classes with varying abilities is hard to do. The input from others towards improvement for the lesson was definitely beneficial.
>
> T2: I learned that I have to expect technology issues during a lesson like this and plan to help students through some of the problems they encounter. I also learned that the students were a great source of assistance for other students when I cannot get to everyone (T1 and T2, Survey of Year 3).

There were comments from teachers concerned about the challenges of implementing lesson study in a high school setting. However, if more practice is attempted, teachers would understand the nature of the lesson study and be able to implement it effectively (Travers et al., 2008c, p. 64).

> T1: Finding time for everyone to spend time on the lesson together.
>
> T2: Common planning time is always the challenge in this type of activity. Getting everyone to agree on a lesson and a method of delivery was also challenging. Continuing the process to improve lessons and not just quit after doing the lesson twice is necessary if the lesson study concept is to be beneficial. It seemed like the teachers delivering the lesson do most of the lesson planning and prep, and that is not the way it appears that it should be done.
>
> T3: Technology problems were a major interference with the process of learning (T1, T2 and T3, Survey of Year 3).

Background information of participants for lesson study. The participants were seven high school mathematics teachers and six high school science teachers for the 2006 school year, and eight mathematics and seven science teachers for the 2007 school year. They were all white teachers who had at least five years experience teaching math and/or science at the high school.

Year 2. There were three male and four female math teachers for the Year 2 project. The math teachers taught Pre-Algebra, Algebra, Intermediate Math, Geometry, Trigonometry, Pre-Calculus, and Calculus. They consisted of veteran and comparative novice teachers, so the veteran teachers led the discussion and delivered the research lesson. One of the veteran teachers was the math department head, and he supported lesson study as a method of professional development. As a result, the math group conducted lesson study as one big group. The novice teachers participated in the lesson study to learn new concepts of collaboration for teaching math.

In the science group, there were three male and three female teachers, and one teacher was the department head, as in the math group. He provided a lot of support for conducting lesson study as a trial for collaboration among science teachers. He led the whole group discussion and was willing to be a volunteer for delivering the research lesson. The science teachers taught Biology, General Science, Life Science, Interactive Life Science, Biochemistry, Chemistry, and Physics. They had a hard time choosing a research lesson due to the differences in their subjects. However, they completed the lesson study with willingness and positivity.

Year 3. The fifteen participants in Year 3 were all white teachers, twelve of whom had returned to the project from Year 2, because they thought that they had learned various and useful strategies and materials with which to teach interactively. Also, even though they had faced some obstacles to lesson study in the previous school year, they viewed it as a generally positive experience. There were three new participants in the project as well, two of whom had

been newly hired as staff members in the fall of 2006. One of these new teachers taught Interactive Life Science and Chemistry; the other taught Geometry and pre-Algebra. The remaining new participant was invited to the project by her colleague who had participated the previous year. She taught special education in collaboration with math.

The twelve returning teachers were comprised of seven math teachers and five science teachers. They shared what they had experienced in Year 2 with the others, and they seemed calmer and more settled when they conducted the lesson study.

Statement of the Research Problem

Lesson study as a method of professional development. Among the various models of professional development, the inquiry model currently seems to be the most relevant. To apply this model, Hawley and Valli (1999) suggest "designing principles for effective professional development" (p. 136). The first principle is that professional development considers "goals and student performance," which means that professional development needs to be "student-centered" and data-driven to increase "public confidence" (p. 139). The next principle is "teacher involvement" (p. 139), which allows teachers to participate in learning activities based on their enthusiasm about improving their teaching. The third principle is that the professional development be "school based" (p. 140). Teachers should implement their professional development into their particular school settings; hence they must integrate what they learn into their daily teaching. The fourth principle is "collaborative problem solving" (p. 141), considered the most important principle because it is inquiry oriented. Although without collaborative problem solving teachers can improve at the individual level, schools cannot reform (p. 141). The fifth principle is that the professional development be "continuous and supported" (p. 141).

Teachers sometimes find the right answer for their teaching context through professional development; however, if the professional development is not sustained to support them over time, they might abandon their attempts to maintain it or even to try new ideas. The sixth principle is that the professional development be "information rich" (p. 142). This is related to the first principle in terms of being data driven, but this principle stresses using the various resources of student outcomes and the learning process provided by professional development. In other words, professional development should offer practical and effective resources for teachers to use in their classroom. The seventh principle is that the professional development provides "theoretical understanding" related to "knowledge and skills" (p. 142). This can be established through research-based teaching in everyday practice. The last principle is that the professional development be "part of a comprehensive change process" (p. 143). Professional development cannot be done as one time shot. Steady support from the school, district, state, and even the national level, including funding, skills, follow-ups, time, or other elements, enable professional development to be sustained as part of a learning process rather than a learning outcome.

Related to the inquiry model, McLaughlin and Zarrow (2001) present "the cycle of inquiry" in order to find signs of teacher and school improvement (p. 80). Figure 1 explains the inquiry cycle. This cycle assists in the understanding of the process of inquiry in terms of implementing teaching strategies and instructional skills learned from professional development.

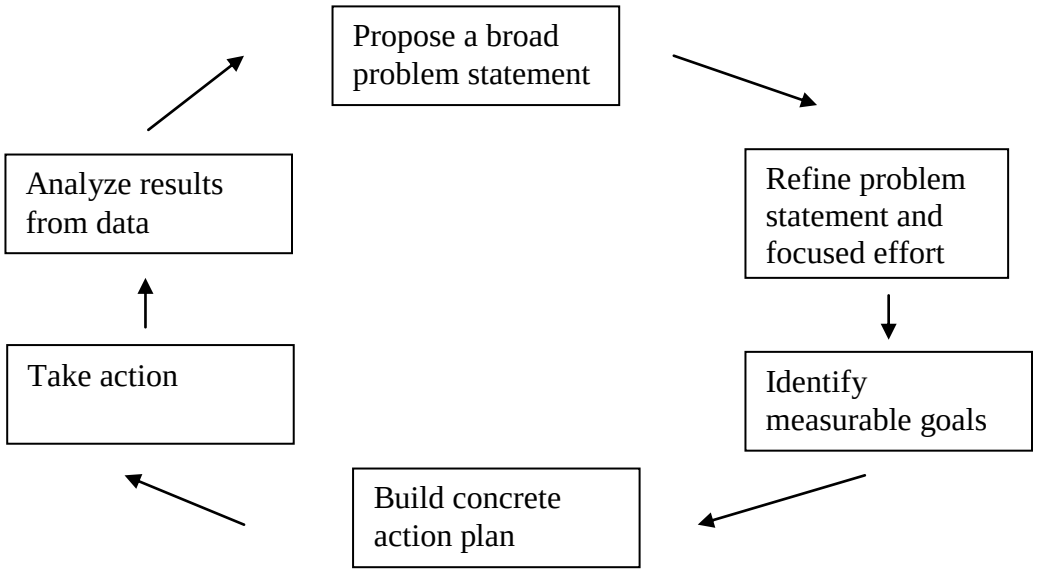

Figure 1. The cycle of inquiry (McLaughlin & Zarrow, 2001, p. 80).

Lesson study has several elements in common with the inquiry model. Lesson study is oriented on research goals and observation of student performance. It focuses on student learning based on teacher instruction, and emphasizes how teachers can improve their teaching based on student performance. It also motivates teachers to become more deeply involved in teaching by spending time studying and discussing their teaching for a concrete purpose.

Like the inquiry model, lesson study requires a school based setting, having originated in elementary school classrooms. Since lesson study stimulates collaboration among teachers, it provides circumstances in which teachers can work with their colleagues. Lesson study has been ongoing in Japan and other countries, including the U.S., receiving various levels of support from teachers, administrators, parents, students, and members of communities, even though some challenges to institutionalization exist. Furthermore, lesson study is driven by data collected by teachers about student performance, so it meets the sixth principle of the inquiry model. Lesson study is an ongoing process of improving and changing instruction, rather than a one-time attempt to determine whether a certain technique works or not.

In summary, lesson study fulfills most principles of the inquiry model of professional development and can therefore be considered a method of professional development. Lesson study might provide more detail about the interaction between teachers and students, evidence of improved instruction and learning strategies, and ample and deeper discussion among teachers based on their observation of student performance. Moreover, since lesson study requires support from administrators, it facilitates the connection of teachers to the school as members of the school community. Thus, this study employed lesson study as a means of professional development in order to examine how teachers implement it independently after the cessation of initial funding.

Difficulties of importing lesson study to the U.S. context. Recent studies focusing on the implementation of lesson study in the U.S. context present several features necessary for improving and expanding the effect of lesson study as a means of professional development. First, more concern about the quality of the curricula is needed (Bass, Usiskin, & Burrill, 2002; Fernandez, Cannon, & Chokshi, 2003; Stepanek, Leong, Mangan, & Mitchell, 2007). The variation in curricula from school to school, or even from teacher to teacher, may make lesson study difficult to conduct. Also, since curricula do not tend to be designed with school-wide goals in mind, teachers may have a hard time selecting topics for their research lessons. Therefore, teachers should focus on a whole unit with respect to the goals, instead of on individual lessons, in order to strengthen their content knowledge (Bass et al., 2002).

Chokshi and Fernandez (2004) revealed "common concerns and assumptions" about bringing lesson study into a new context, such as the U.S. Since lesson study is an "exotic idea" (p. 521) from Japan, many feel that it could not be implemented in America. For one, lesson study is time consuming, and it is difficult for American teachers to find the time to do a lesson

study. In addition, there is a lack of evidence explaining the impact of lesson study on improving student achievement. Therefore, it has not yet been shown whether lesson study really does improve instruction or increase student achievement. Due to insufficient knowledge of content, U.S. teachers may have some difficulty implementing a lesson study. Finally, some people think that U.S. teachers are more nervous than Japanese teachers, and are reluctant to open their classrooms to others or collaborate with colleagues.

In addition, lesson study as a method of professional development needs to be understood fully in terms of cultural context when it is imported to the U.S. Describing the dissimilarities between Japan and America, Crockett (2007) points out that "Japanese teachers view teaching and learning differently than do U.S. teachers" (p. 614). Japanese teachers think that "teaching and learning are a constitutive practice," but American teachers consider teaching and learning as separate activities with a linear relationship (p. 615). From a more cultural perspective, Crockett states that lesson study illustrates "professional development as a natural part of what Japanese teachers do" (p. 617), which is conducted within "a systemic and nation-wide effort linked to specific school goals" (p. 617). For American teachers, on the other hand, professional development as research tends to occur as "a research intervention," and they may come from different schools and may not focus on the goal of school improvement as Japanese teachers do (p. 617). Crockett explains that because Japanese teachers embed student thinking in pedagogical decision making, "dualisms" are not maintained, such as including content vs. instructional knowledge, or student vs. teacher thinking about mathematics (p. 619). Overall, she emphasizes the radical discrepancy between Japanese and American culture in terms of professional development. In order to implement lesson study in the U.S. context, these cultural differences need to be considered.

The issues surrounding the import of lesson study into the U.S. context, while challenging, are not insurmountable. This study focused on such challenges and possible solutions, in order to establish lesson study in the U.S.

Implementing lesson study in the high school setting. Fernandez et al. (2003) completed a lesson study in which American teachers collaborated with Japanese teachers. Sixteen teachers and administrators participated in this study. The Japanese teachers facilitated the lesson study for the American teachers to implement in their classrooms for the first time. Videotapes, field notes of meetings and lessons, products of lessons, and interviews were collected as data and analyzed. The researchers found several challenges in adopting a lesson study: developing "meaningful and testable hypotheses," choosing proper methods for "exploring these hypotheses," using the evidence to evaluate the research outcomes, and documenting the findings of research for generalization (p. 173). They also noted the concerns of the Japanese teachers about implementing Japanese lesson study in the American context. First, more interest and consistent effort for developing curricula are needed (p. 177). Next, a deeper understanding and investigation of student outcome is also needed (p. 179). Overall, they concluded that a lesson study was a beneficial opportunity for American teachers to think about their teaching and students' learning in order to change their perspectives.

Similar to the previous study, Perry and Lewis (2008) conducted a four-year lesson study. They focused on how lesson studies worked and were adopted at the district level. A California K-8 school district participated in the lesson study from 2000 to 2004. Interviews of approximately 70 teachers and administrators, observations, audio and video tapes, and "artifacts of lesson study practice" of about 20 lesson study groups comprised the data of this study (p. 4). Teachers had learned about the lesson study through various activities: "school year participation,

workshops, public lessons, and other events" (p. 5). They changed the point of the lesson study from "an instructional product" to "a process of instructional movement" with four kinds of impact: more reflection and feedback, a clearer understanding of "protocols and tools," more resources of "external knowledge," and more attention to "student thinking" (p. 7). Thus, the possibility of adopting lesson study in an American public schooling at the district level was explored. However, a better understanding of lesson study, construction of teachers' professional learning communities, and distribution of teacher leadership would have improved the lesson study.

These two representative examples of lesson study implementation in the U.S. context were conducted in K-8 school settings. Due to the origin of lesson study in elementary schools, not much research has been completed in high school settings. Therefore, this study spotlighted high school teachers' implementation of lesson study with various concerns about teaching and learning, subject matter, students, classroom circumstances, and instructional improvement.

Purpose and Research Questions

The purpose of this study was to examine how lesson study was implemented as a method of professional development in high school mathematics and science settings after funding had ceased. Specifically, this research investigated the collaboration among teachers implementing lesson study (Fernandez, 2005; Takahashi & Yoshida, 2004), the importance of which was emphasized by Lewis (2002) for devising long-term student learning goals. In addition, this study explored the interaction between me as a facilitator and the participants.

As previously discussed, the practical details of implementing lesson study and its benefits for teaching were the main point of the research questions. First, since collaboration was

important, the ways in which participants conducted lesson study independently after the end of funding was considered. This helped clarify what teachers knew about lesson study and how they collaborated with other colleagues within the lesson study, as well as how they implemented the lesson study without funding.

Next, sharing ideas of teaching and learning, and combining new and current knowledge was important to the improvement of teachers' instruction. Making meaning of teaching and learning was also important to the development of instructional knowledge. This study looked at how teachers achieved improved instruction through lesson study if they did so. In addition, this study considered emerging challenges for teachers conducting the lesson study independently without funding.

In summary, this study was guided by the following questions:

How did teachers in a high school setting who had experienced lesson study before implement their work after the funding for their lesson study had ceased?

1. What did teachers do independently to implement lesson study?
2. What kinds of support did teachers need to implement lesson study?
3. What were benefits for teachers?
4. What were challenges for teachers?
5. In what ways, if any, could lesson study be continued?

Definition of Terms

Professional development.

Professional development is critical to ensuring that teachers keep up with changes in statewide student performance standards, become familiar with new methods of teaching in the content areas, learn how to make the most effective instructional use of new technologies for teaching and learning, and adapt their teaching to shifting school

> environments and an increasingly diverse student population (Lawless and Pellegrino, 2007, p. 575)

Professional development in the field of education focuses on skillful instruction and successful classroom management strategies, based on a solid understanding of student learning. Professional development has become an important factor in the overall improvement of education (Elmore & Burney, 1999; Guskey, 1995). Professional development impacts teachers in many ways, including the encouragement of teachers' personal growth (Darling-Hammond & McLaughlin, 1999), the improvement of teachers' knowledge and practice (Ball & Cohen, 1999), the incorporation of reflection from the experts (Elmore & Burney, 1999), and the construction of a "professional learning community" and a "teacher learning community" (Westheimer, 2008, p. 757).

Furthermore, Little (1993) addresses the characteristics of effective professional development. These characteristics include appropriate collaboration, active involvement in practice, reflective development of instruction and curriculum, well organized learning procedures, and collaborative endeavor as a disposition of teachers.

Lesson study. In Japanese, the term "lesson study" is made up of two words: *jugyo*, meaning "lesson," and *kenkyu*, meaning "study" or "research" (Fernandez & Yoshida, 2004, p. 7). Fernandez and Yoshida (2004) explain that "lesson study consists of the study or examination of teaching practice" (p. 7). Similarly, Shimizu (2002) asserts that "lesson study is a common element in Japanese educational practices" (p. 53).

Within the American context, Lewis (2002) explains that "lesson study is a cycle in which teachers work together to consider their long-term goals for students, bring those goals to life in actual 'research lessons,' and collaborate to serve, discuss, and refine the lessons" (p. 1). Stepanek et al. (2007) state that "lesson study is a professional development practice in which

teachers collaborate to develop a lesson plan, teach and observe the lesson to collect data on student learning, and use their observations to refine their lesson" (p. 2).

There are, therefore, differing views as to whether the term should be translated into English as "study lesson" or "research lesson." Based on several articles related to lesson study, "study lesson" seems to be used to describe a lesson study in the Japanese context, while "research lesson" is used to talk about the use of Japanese lesson study in the American context. For instance, the term "study lesson" is used for describing the lesson study process by Japanese scholars (Fernandez & Yoshida, 2004; Isoda, Stephens, Ohara, & Miyakawa, 2007; Shimizu, 2002). In contrast, Lewis (2002) uses the term "research lesson" to talk about a lesson for science research in lesson study; Stepanek et al. (2007) and Wiburg and Brown (2006) both use the term "research lesson" as evidence of the acceptance of Lewis's notion of the term.

The term "study lesson" is likely more about acquiring content knowledge through study with other peers in a small group. Teachers attempt to optimize the lesson (Fernandez & Yoshida, 2004) for their students' understanding of its objectives based on careful consideration of all possible resources related to the study lesson. They focus on the quality of the lesson as a top priority. However, the term "research lesson" seems to be used to describe an experimental lesson (Lewis, 2002) for their teaching and student learning. Teachers emphasize the implementation of the lesson, so reflection on their teaching and observation is regarded as the main concern of the lesson study. In conclusion, even though these two terms reflect different insights, they represent a vital element of lesson study which allows teachers or researchers to understand how to improve teaching and learning.

Among these various explanations of lesson study from different perspectives, there are several commonalities. Lesson study is the study or research of lessons with careful examination

of materials and instructions related to the lesson in order to improve teaching strategies or skills based on students' behavior as data. To understand what lesson study is within not only the Japanese context, but also the American context, the next chapter will address the lesson study process, format, and points of view in more detail, based on a review of the literature.

Limitations of the Study

This study was not aimed at generalizability, but rather designed to produce unique and valid assertions about a specific context. Thus, this study offers a rich case study of the implementation of lesson study conducted by high school math and science teachers in order to expand the possibilities of implementing lesson study in secondary mathematics and science education.

Another limitation of this study was the various levels of experience of the participants. Some of the participants had experienced lesson study twice as a means of professional development related to the university partnership, while some had experienced lesson study only once or even not at all. They did not have the same level of participation, so this fact might have affected the implementation of the lesson study. Some teachers, for example, may not have fully understand what lesson study was and therefore may not have been as active as they otherwise may have been.

One more limitation of this study was my bias and previous experience with lesson study. Since I had several years' experience with lesson study in a different cultural context (Korea), I might have had preconceptions which lead me to evaluate the lesson study rather than facilitate it while I was conducting this research. My personal experience with lesson study is discussed in a later section.

Significance of the Study

Most professional development programs are funded. Therefore, once the funding ceases, the professional development program cannot continue no matter how beneficial it was for teachers. This phenomenon has led educators to consider how to maintain high-quality programs for teachers without a concern for funding. According to recent research, consistent and well-organized support is needed through structured professional development for in-service teachers to acquire knowledge through daily teaching. This includes structuring knowledge as a craft, reflecting on teaching, and inquiring into practice (Cochran-Smith & Lytle, 1999). Well-supported teachers can play a critical role in developing "knowledge-in-practice" (Cochran-Smith & Lytle, 1999. p. 250; Fernandez, 2002; Lewis, Perry, & Hurd, 2004), regarding students' inquiry-based learning processes. However, there is still a lack of research on what happens after the initial funding ceases. This study shows what really happens when the funding ceases, which might reveal ways to construct a professional development program that can continue for a long time without funding.

In addition, this study looks at how lesson study can be a continuous method of professional development since it allows, among other things, for teachers to have a clear idea of their strengths and weaknesses (Fernandez & Yoshida, 2004), and enables them to be reflective on their teaching and students within collaborative environments despite the fact that lesson study work is time consuming (Fernandez, 2005). Lesson study also allows teachers to gain vital information that can be used to improve their teaching skills (Fernandez & Yoshida, 2004). It offers teachers the opportunity to discuss content with an open mind and a willingness to share their experience (Fernandez & Yoshida, 2004; Fernandez, 2005). It helps teachers make a connection between "educational goals and standards" and daily life in the classroom (Lewis,

2002; Takahashi & Yoshida, 2004). It fosters data-driven teaching improvement and student-centered teaching in order to reach many students (Lewis, 2002). Therefore, this study presents how teachers implement lesson study without funding based on their previous experience with funded lesson study. The positive and negative perspectives of implementing lesson study without funding are the main focus of this study, although the elements needed to conduct lesson study with funding are analyzed as well.

Due to the origin of lesson study, it tends to be conducted by elementary teachers. This study focuses on the implementation of lesson by high school math and science teachers. This fact might extend the insights into lesson study in high school education, providing practical guidance for high school teachers to implement lesson study to improve their instruction.

Overall, this study provides a critical framework for examining and assessing how lesson study was implemented without funding but with practical support from the facilitator and administrators, despite repeated challenges and limited impact on teaching and learning in high school math and science education. Consequently, this study helps to lend some perspective as to the possibility of continued implementation of lesson study as a method of professional development after the initial funding has ceased via support from the school and facilitators within a high school setting.

My Personal Perspective

My personal perspective as I approach this study is influenced by the lesson study that I participated in during my four years of teaching in Korea. Thus, in this section there will be no references to any published sources for citations, but rather an illustration of my lesson study experience. I had my first experience with lesson study in the pre-service program of my

university. Much as Japanese teachers conduct lesson study, my peers and I collaborated in a small group to create a lesson plan, observe one another's teaching (although in this case, the students were my colleagues rather than elementary students), discuss our observations and reflections, revise the lesson plan, and re-teach it. After the whole process, all of the peers discussed what had been learned. Subsequently, I implemented a lesson study when I became a classroom teacher. Since I taught fifth grade my first year, my small group of fifth grade teachers focused on one fifth grade subject (e.g., mathematics or science). I played a small role in the lesson study process, recording discussion comments, because I was a novice teacher in that school environment. Thirteen teachers conducted the lesson study according to the procedures of the Japanese lesson study that first semester.

However, the second semester, the process of the lesson study changed. All thirteen teachers chose a different subject area or different content areas of the same subject, and then created a lesson plan themselves according to their personal goals related to school improvement. For instance, I chose science and wrote a lesson plan for the reaction of indicators to acids and bases. After individual lesson planning, all teachers taught their lessons on the same day, so the teachers of other grades observed our classes in order to bring expanded teaching experiences to the process and to obtain new perspectives on our teaching. In this school context, all of the teachers taught a different grade each year. Therefore, it was valuable to observe teachers and students from other grades. If one teacher wanted to stay at the same grade level for a while, that would be acceptable, but it was not recommended that the teachers stay in the same grade over three years, because all teachers moved to another school every five years.

As the Korean education culture is different from the Japanese education culture, the lesson study was not implemented in the same way, but thanks to some similarities (e.g., national

curriculum, teachers' gathering culture, and willingness to open their classrooms to others) lesson study has been established as a professional development activity. Lesson study helps Korean teachers to create a professional learning community focused on student learning and improved teaching.

I hoped these experiences with lesson study would allow me to gain a deeper insight into lesson study and to facilitate lesson study for all the participants in this study in order that they would develop and continue their professional learning community through lesson study as a method of professional development.

Chapter 2

Review of Literature

This chapter investigated the literature related to professional development and lesson study. A section of professional development included major models/approaches of professional development, issues of professional development and continuity related to it, and the role of facilitators. The other section of lesson study contained an overview of lesson study as a method of professional development, important insights and challenges of importing lesson study, and key elements of lesson study related to continuity.

Professional Development

Garet, Porter, Desimone, Birman, and Yoon (2001) discuss different types of professional development activities. They divide these activities into two groups: traditional and reformed. The traditional group includes workshops, institutes, courses, and conferences; the reformed group is comprised of study groups, mentoring, peer coaching, and collective participation (p. 920). The workshop is a common professional development activity used for introducing new developments in education. It requires special experts in teaching and learning from outside the teachers' classrooms. It is delivered within various timeframes, depending on schools' schedules (e.g. weekend, summer, or after school). In addition, institutes, courses, and conferences can be considered workshops, because they include professional experts who facilitate participants' engagement in the learning process in order to improve their teaching.

On the other hand, study groups, mentoring, and peer coaching are considered reformed activities. Reformed activities occur during regular school time instead of requiring extra time, and focus on the relationship between advances in education and classroom teaching. Reformed

activities are also designed to be sustainable, so that schools can implement them over and over, based on teachers' active participation, and to be appropriate to teachers' actual needs (p. 921). For instance, a mentoring program has been established in many schools as a form of ongoing professional development. It facilitates connections between novice and veteran teachers, so that novice teachers are able to adapt to the new environment, and it encourages improved teaching in terms of the integration of curricula and classroom management. In addition to study groups, mentoring, and peer coaching, more elaborate forms of professional development activities have been created, such as university partnership, ongoing visitations, and practical courses related to real school teaching.

Major models/approaches professional development. Two important studies address the major approaches or models of professional development in the 90's: *Teacher professional development* from Sprinthall, Reiman, and Thies-Sprinthall (1996), and *The essentials of effective professional development: A new consensus* from Hawley and Valli (1999).

Sprinthall et al. (1996) present six different models based on emerging issues and time periods. They mention three early models first: "the trait and factor model," "the dynamic model," and "the process-product model" (p. 666). The first of these, the trait and factor model, focused on fixed personal characteristics, and it did not provide a firm relationship between teacher selection and teacher education, because individual personality could not affect developing research and theory. To avoid these limitations, the dynamic model emerged, based on a psychological approach. This model took into consideration the connections between mental development and physical behavior. However, it did not focus on the improvement of teaching. Finally, the process-product model was formed in order to overcome the deficiencies of the first two. The process-product model noted how teacher behavior impacted student

learning, based on the assumption that well-developed teaching skills can increase student achievement. Nevertheless, it missed the point that teaching is not a one-way activity, but rather requires interaction between teachers and students, as Shulman (1986) claimed in a Sprinthall et al. (1996) article (p. 666).

Next, Sprinthall et al.(1996) address three more current models, all based on qualitative and quantitative empirical studies: "the craft model (p. 667)," "the expert model (p. 682)," and "the interactive model" (p. 687). The craft model emphasizes teachers' well organized and developed experiences, which allow them to construct knowledge and to build wisdom. It enables a network of teachers to support one another at the school or district level. Although teachers support one another in this model, its implementation is limited in some school settings, because of varying needs according to different school contexts. The expert model requires important information and skills developed by experts or professional teacher educators. For instance, novice teachers need effective advice from veteran teachers. The aim of the expert model is not to create a network among teachers, but to assist in the "intellectual growth" of teachers through a workshop activity. Finally, the interactive model encourages teachers to become actively involved in the learning process. This model requires teachers' reflective feedback on their teaching, and their improvement is based on those reflections.

From a slightly different perspective, Hawley and Valli (1999) explain five models of professional development: "the individual guided model, the observer/assessment model, the development/improvement process model, the training model, and the inquiry model" (p. 135). The individual guided model stresses the individual development of each teacher. It supports teachers' personal growth, since they participate in their own learning opportunities, but it might not affect school improvement if there is no connection between a teacher's classroom teaching

and school improvement. Secondly, the observer/assessment model facilitates the sharing of teacher feedback, such as peer coaching, based on observations. In this model, coaches have to be responsible and reliable because the quality of the professional development depends on their ability to manage a variety of resources and to deliver knowledge with trust.

The development/improvement process model encourages teachers to become involved in "design curriculum" and to participate in "a school improvement and problem solving process" (p. 135). A well known model, the training model is delivered through a workshop activity. This model assumes that teachers may acquire new perspectives such as "belief, knowledge, and behavior and performance of their students" (p. 135) through the workshop. Finally, the inquiry model, regarded as "the teacher-researcher model" (p. 135), requires teachers to take on a new role as researchers, investigating a certain area they are interested in and improving their teaching based on the interpretation of collected data.

Issues of professional development. Based on a review of the literature surrounding professional development, five main points summarize what is needed for the implementation of a research project for building the professional development circumstance.

First, professional development should be on-going. Continuous support is the most important factor for professional development (Akiba, LeTendre, & Scribner, 2007; Elmore & Burney, 1999; Garet et al., 2001; Guskey, 1995; Wilson, Peterson, Ball, & Cohen, 1996). Related to this matter, funding plays a very important role in professional development. "Funds should be focused" (Garet et al., 2001, p. 937) and money is required for professional development (Barone, Berliner, Blandchard, Casanova, & McGowan, 1996; Elmore & Burney, 1999). However, it is not easy to collect funds for maintaining professional development (e.g., the Algebra Project). Thus, professional development educators attempt to create similar

projects with continuity and coherence in terms of the content, methods, or structure of a professional development program as a one of the possible ways to maintain professional development over time. Generally speaking, continuous aid and assistance with stable funding would be effective for in-service teachers.

Second, professional development should provide qualified knowledge of content, instruction, and student learning. Since teacher quality is a commonly recognized for its impact on student achievement (Akiba et al., 2007; Barone et al., 1996), increasing teacher quality through professional development is crucial. Professional development needs to recognize teachers as mature and professionals learners first (Hawley & Valli, 1999), then offer well organized and prepared knowledge related to practice (Cochran-Smith & Lytle, 1999), to content (Elmore & Burney, 1999), and to teachers' learning (Wilson & Berne, 1999). Although knowledge contains numerous components, content, instructional, and learning process knowledge are significant for teachers throughout professional development.

Third, professional development should be standards-based not only for staff development standards, but also for nationwide standards in each subject. Standards are "logical extensions" of professional development (Elmore & Burney, 1999). Therefore, the National Staff Development Standards (hereafter NSDS) can be used as the criteria for what to teach, how to teach, what to include, what to consider, and other issues of professional development (e.g., context, process, and content in NSDS). Besides NSDS, standards for each subject area (e.g., NCTM standards in mathematics and AAA's benchmarks in science) enable teachers and educators to improve and develop their knowledge of content and instruction based on student learning. As professional development requires specific strategies of implementation (Elmore & Burney, 1999), those standards provide directions to follow for effective results.

Fourth, professional development should consider teachers' needs for their current practice. In order to create this relationship, professional development ought to supply the necessary motivation for teachers to participate actively (Seidel & Shavelson, 2007), allow for the flexible integration with other contexts (Guskey, 1995), be practice based (Ball & Cohen, 1999), and provide learning opportunities for integrating outside knowledge into practice (McLaughlin & Zarrow, 2001). Moreover, professional development needs to be aware of teachers' voices and opinions developed through their daily practice in order to strengthen the relationship between theory and practice.

Finally, professional development should encourage teachers to become practitioners of research on teaching and learning in professional learning communities. This notion of practitioner-researcher originates in inquiry. As Putnam and Borko (1997) mentioned teachers must be regarded as energetic learners who build their own comprehension, teachers are required to research their own practice and to reflect in order to improve their teaching. In addition, teachers can do so with a team (Guskey, 1995), within learning communities (Cochran-Smith & Lytle, 1999; Darling-Hammond & McLaughlin, 1999; Westheimer, 2008), while focusing on "learning process, motivational-affective outcomes, and cognitive outcomes" (Seidel & Shavelson, 2007, p. 485). If the learning community is embedded in school settings and established teacher communities, it can become a solution to institutionalized issues of professional development.

Overall, there is no single factor of effective professional development that impacts work strongly enough to improve practice. The growth of professional development requires the harmony of all the factors addressed above. However, there are more insights into professional development. Numerous studies of professional development focus on the improvement of

teaching, but not on the relationship between teachers' instructional practice and students' learning. As Crockett (2002) asked, "How is improvement in student learning linked to these activities?" (p. 623). The connection between teachers' practice and students' achievement needs deeper investigation. Also, professional development requires the understanding of social justice issues (Noffke & Zeichner, 2006) in theory and practice. If research into professional development is designed to address the issues in this section, it would be very powerful and meaningful for the improvement of professional development.

Continuity of professional development. Related to the previous section, several studies of professional development discussed their possible continuity related to the well-organized content of professional development programs. Wilson et al. (1996) claimed that four points are needed to enhance and continue professional development programs: they needed practical examples of classroom teaching, constant reflection, various perspectives from different contexts, and awareness of the practitioner in teaching. Similar to those ideas, Klingner, Ahwee, Garderen, and Hernandez (2004) outlined the characteristic needed to make professional development sustainable: They should be research oriented, provide appropriate support for teachers, help for improved knowledge, and proper assessment of the effectiveness of the professional development program.

Tafel and Fischer (2001) illuminated the factors that contribute to the sustained relationship between professional development and school improvement. It was important to encourage rapport among peers, to allow for their autonomy in developing curriculum and building learning communities, to provide reflection on their teaching for their improved knowledge about teaching and learning, and allow active collaboration with other teachers.

In summary, all concerns discussed above are significant to continue professional development in a certain context. Once a professional development program is introduced to teachers, it should be concerned about their practical needs and issues stimulate them to become active researchers on their teaching, encourage them to work together, and let them construct professional learning communities in their contexts. If those conditions are arranged, professional development can be continuous and ongoing.

The role of facilitators. Facilitators are a key factor in implementing professional development programs at any setting because they enable participants (usually teachers for educational contexts) to understand the main themes and goals of programs, to improve instructional and content knowledge, and to achieve beneficial practices. It was not easy to find proper facilitators for professional development programs because relative interests and knowledge were needed for a facilitator to implement programs (Sandell, Wigley, & Kovalchick, 2004). Next, researchers have found that establishing a community for facilitators was significant in order to enhance the effectiveness of programs. They described activities for facilitators to develop in order to continue the professional development program. They must clarify themes and outcomes, connect themes and outcomes, develop community and build practice, plan details, assess and evaluate, and sustain programs.

To find out the detailed roles of facilitators, Lindqvist and Reeves (2007) found that facilitators have primary training and weekly meetings in order to share their experience and collaborate with other facilitators. As a result, they promoted the better practice of participants based on those debriefing and discussion sessions. Moreover, the attitude of facilitators was very crucial to implement professional development programs and included positive traits such as "enthusiasm, humour and empathy" (p. 404).

Bush (2008) stated the practical role of facilitators was to be aware of their role as facilitators, pay attention without criticism, be flexible in different perspectives, share challenges, be patient and persistent, be focused on presenting evidence, be collaborative, discuss collected facts, and ask reasonable questions of the protocol. Similar to his assertion, Le Fevre and Richardson (2002) claimed that facilitators were responsible for "organization / action planning, resource provision, advocating for student needs, and teacher coaching / facilitation of dialogue." (p. 492). Interestingly, they mentioned dilemmas which facilitators might have such as building trustful and confident relationships with participants during the professional development programs, making a balance of "individual autonomy and external direction" (p. 494), and setting the agenda properly.

More specifically, Perry, Komesaroff, and Kavanagh (2002) examined the role of the facilitator in a school-university partnership. They found that there was an uncertain understanding of the role of the facilitator from school teams and universities. Therefore, both teams needed to know more clearly the role of the facilitator and to develop practical and continuous expectations for the facilitator.

Overall, the role of facilitators was explained with various perspectives based on previous research. First of all, facilitators should clearly know their roles before implementing any professional development program (Bush, 2008; Perry et al., 2002). Next, they need to develop the content and agenda for programs (Le Fevre and Richardson, 2002; Perry et al., 2002; Sandell et al., 2004). Third, they should be enthusiastic, flexible, respectable, patient, persistent, and have consideration for participants (Bush, 2008; Lindqvist & Reeves, 2007). Lastly, they need to attempt to overcome emerging challenges while implementing programs (Le Fevre & Richardson, 2002).

Lesson Study as an Effective Method of Professional Development

Overview of lesson study in Japan. Japanese mathematics education was influenced by foreign teachers in 1892 in order to establish the notion of "whole classroom instruction" instead of "individualized instruction" (Isoda et al, 2007, p. 10). After that time period, Japanese teachers needed to learn how to teach from a newly developed textbook through "open classes" (p. 12) as a model of teaching developed from a book of Pestalozzi's teaching method: "teaching materials," "observation," and "critique sessions" (p. 12). They observed other teachers' classrooms to understand how new ideas or curricula were taught, and to apply what they learned to their own classroom. The idea of "open classes" was the origin of lesson study. Since the 1920s, the "problem-solving" approach to mathematics teaching has been developed and disseminated through lesson study, which has been introduced based on case studies of Japanese mathematics education. Three groups of researchers describe the idea of lesson study in detail from similar but slightly different perspectives.

Isoda et al. (2007) explain that lesson study has three stages: "preparation, actual class, and class review sessions" (p. 2). All three stages are developed in collaboration with teachers, which is a crucial component of the lesson study process. The "preparation" stage refers to planning the curriculum, so it includes the discovery and selection of relevant materials for teaching to the objectives of the class, improving instructions based on students' needs, and documenting all information in the lesson plan. Teachers select topics for lesson study with regard to "goal, content, and index for evaluation" (p. 5). Next, the lesson plan is implemented in the actual classroom, and this lesson is called a "study lesson" (p. 3). While one teacher is teaching it, many other teachers, educators from universities, or supervisors from the education board observe the classroom teaching. After observation, they participate in the review session,

which is the third stage of lesson study. All participants discuss the implemented lesson and revise it to produce a more appropriate lesson based on their evaluation. First, teachers who develop the lesson plan present its goals, and then the rest of the observers ask questions about problems, instruction, or student response. The purpose of this review session is to explore ways to improve teaching by searching for any disconnect between the goals of the lesson and what actually happens in the classroom. After this third stage, teachers start over at the first stage with the revised and improved lesson plan. Overall, lesson study is a valued method for supporting teacher improvement and fostering a connection between theory and practice.

In addition, Isoda et al (2007) address "the key ideas underlying lesson study" (p. xvi). Teachers are able to learn from other teacher by observing their teaching, and to improve their teaching based on those observations. Teachers who have a solid knowledge base in certain subject areas can share their knowledge with peers. Lesson study seems to lead to teacher centered improvement, but it radically focuses on student learning (p. xvi).

Fernandez and Yoshida (2004) present an overview of lesson study from a slightly different point of view. Lesson study consists of six steps to be conducted: (1) "collaboratively planning the study lesson," (2) "seeing the study lesson in action," (3) "discussing the study lesson," (4) "revising the lesson (optional)," (5) "teaching the new version of the lesson (optional)," and (6)"sharing reflections about the new version of the lesson" (pp. 7–9). Teachers as a small group (e.g., same grade group) design a lesson plan according to the first step, based on their individual teaching experience, an understanding of current students, and other resources, including textbooks and teachers' guides. One of the teachers teaches the lesson plan as the second step. During the teaching, the rest of the teachers involved in the first step observe the classroom. They debrief about their observations for effective changes in the lesson plan. After

this third step, they decide whether to implement another trial of the lesson or not. If they decide to do so, they revise the lesson based on their discussion, and then one of them teaches it again with the agreed-upon improvements. Other teachers in the group observe the classroom again to see how those changes affected teaching and learning. In this step, it is not common that the same teacher teaches the lesson again, or the third teacher in the group teaches the lesson again. Finally, as a whole group, they reflect on their observations, feedback, and suggestions about the lesson, and then they document their discussion.

With a quite different form, Shimizu (2002) describes "how lesson studies are structured and delivered" (p. 54). He outlines three phases: before, during, and after. Before the lesson study is delivered, teachers decide on a theme, select a specific topic for the lesson, plan a lesson, teach the lesson, and discuss and revise after teaching. During the lesson study, they observe the lesson and reflect on the teaching while they discuss. After the lesson study, they apply the results of their discussion to the following lessons, identify the next theme, and report their procedures and findings for outside teachers.

Although the process of lesson study is described in various ways by different researchers, it has some common features. The first common feature is planning the lesson. The next one is teaching the lesson and observing its implementation. Discussing the observation and reflection, followed by revision comprise the third step. Finally, the last step includes re-teaching and re-debriefing, with a report. This is the basic outline of the lesson study process, but as it moves forward, the model is likely to grow in a spiral shape, because the designed lesson would be taught by many other teachers. Hence, the lesson would be improved and developed over and over again.

Overview of lesson study in the U.S. context. Lesson study has emerged in the United States as a form of professional development. The lesson study movement "was inspired by The Teaching Gap" (Stigler & Hiebert, 1999, as quoted in Takahashi, 2007, p. 194). It has begun to be introduced by several researchers (e.g., Lewis, Yoshida, and Fernandez), particularly through documentation of "the Third International Mathematics and Science Study (TIMSS, 1995)" (Lewis, 2002, p. 15).

Lewis (2002), a well known scholar in lesson study in the United States, describes the "lesson study cycle" (p. 3). She emphasizes collaboration among teachers in order to devise goals for "student learning and long-term development"; deliver the lesson with one teacher teaching and other teachers observing, with a focus on "student learning and development"; debrief about observations and reflections and applying the results of discussion to the improvement of the lesson; and conduct the revised lesson by another teacher, "if desired, and study and improve it again" (p. 2). Figure 1 shows her perspective of the lesson study cycle in more detail.

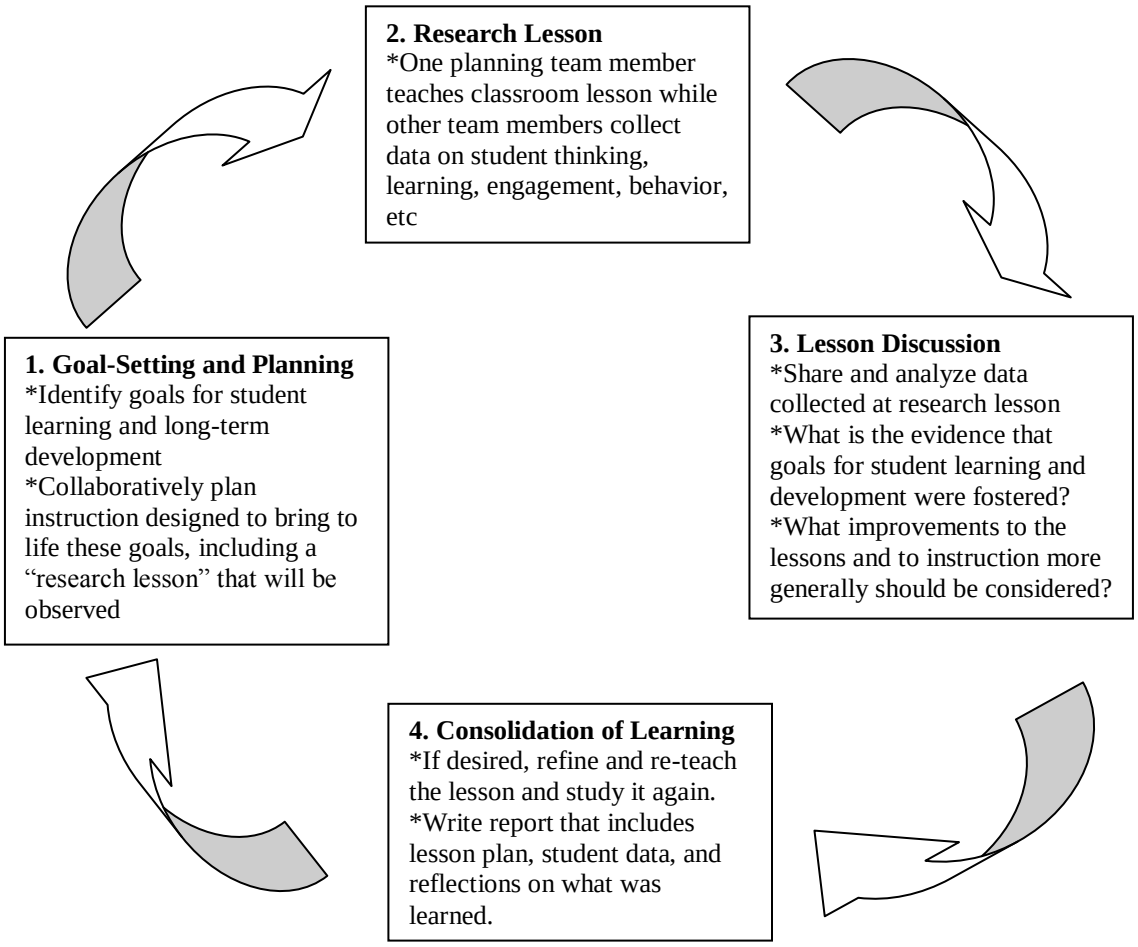

Figure 2. Lesson study cycle (Lewis, 2002, p. 3).

Another group involved with lesson study, Stepanek et al. (2007), states the lesson study process: "setting goals," "planning the lesson," "teaching, observing, and debriefing," "revising and re-teaching," and "reflecting and sharing results" (pp. 5–6). First, teachers find research which enables them to understand effective teaching for student learning. Next, they design a detailed lesson plan in order to research the goals of the lesson. Then, one of the teachers teaches the lesson while others observe the classroom. After teaching, they share their observations of students' learning. Based on debriefing, they revise the lesson plan, and another teacher teaches it again. At last, they report what they are doing in the lesson study to disseminate their findings for the improvement of teaching as a profession.

Wiburg and Brown (2006) describe the lesson study cycle that they have been using for four years. The lesson study process contains six steps. Teachers identify "the problem" and establish "the overarching goal" (p. 5) in step 1. They develop "the research question" (p. 5) in step 2, and they design "the research lesson" (p. 5) in step 3. They teach the lesson and observe it in step 4, and after that they debrief, reflect, and revise the lesson in step 5. In step 6, they share what they learned.

Similar to the Japanese context, the process of lesson study is described in various ways, but it has some common features as well: planning the lesson, teaching the lesson and observing its implementation, discussing the observation and reflection, and revising the lesson. However, re-teaching and re-debriefing with reporting seem to be optional in the U.S., because the priority of conducting the lesson study in the U.S. at this point is introducing the idea to American teachers. The important thing is to encourage teachers to expand their view of teaching improvement, rather to force them to follow the exact same process or procedure of lesson study without a full comprehension or an optimistic attitude. In light of these concerns, the next section will discuss how American teachers can implement lesson study in their classrooms with practical direction.

Implementing lesson study in the US context. Because lesson study is an idea imported from another culture, lesson study in the U.S. context needs to be carefully guided, with detailed steps to follow. Lewis (2002) introduces "a step-by-step guide" (p. 51) to adopting lesson study. The first step is forming "a lesson study group" (p. 51) in a school. Recruiting group members voluntarily, making a commitment to spending time on the lesson study, setting meeting schedules, and accepting the basic rules for maintaining the group are the major

activities of the first step. To encourage teachers to get involved, the group needs to emphasize discussion, collaboration, and student learning as evidence of teaching improvement.

Focusing the lesson study is the second step (p. 55). In this step, group members should find a possible research theme, select a specific subject, and choose a unit and lesson. When they find a research theme, they have to consider the long term goal of school or curriculum improvement. Also, it is important to determine which concepts or skills in a particular subject area are difficult for students to learn, or for teachers to teach, in order to choose a topic for the lesson study. Based on the second step, the group plans "the research lesson" (p. 62) as the third step. This step is crucial, and it is where teachers spend most of the time for the lesson study, because they should "study existing lessons" and "develop a plan to guide learning" (p. 62) in this step. They attempt to make the best lesson plan for students to learn effectively through the lesson based on their studied resources. Outside perspectives from educational experts (e.g., professors, supervisors, or principals) help the group expand their points of view about teaching and learning in this step.

Fourth, teaching and observing the research lesson is the next step (p. 67). One group member teaches the research lesson, and then the rest of them--and outside participants--observe the classroom. It is important that observers not interact with students, but just collect data about student response to the teacher's instructions to compare to the lesson plan. After teaching and observation they discuss the research lesson. There are several elements to be included in the discussion of the research lesson: the teacher's "reflections," "background information" of the research lesson group, conversation of the research lesson, "general discussion" focused on student learning, comments from outside experts, and "thanks" to all participants (p. 69).

Lastly, the group members need to revise the lesson plan based on their discussion and analysis of the research lesson (p. 70). After that revision, they should "reflect on" the lesson study and "plan the next steps" (p. 71). While Japanese teachers do this step after implementing another cycle of lesson study, American teachers need to think about this step before doing so, since the first cycle of lesson study is a new experience for their teaching. They should fully understand what lesson study is in order to implement it in their classrooms.

The Japanese scholars Takahashi and Yoshida (2004) focus specifically on how to begin lesson study in mathematics education. First, teachers need to create "an informal study group" (p. 438)--not necessarily school wide to begin. The purpose of the group is to focus on "improving mathematics teaching and learning" (p. 439). It can become an initiative group for lesson study later. In the next step, the group should "experience lesson study" (p. 439). Although lesson study is a sophisticated process (Lewis, 2002) with a simple meaning, teachers should learn what lesson study is through participating in the lesson study process. In order to do so, teachers in the group need to find the "research goal or theme" (p. 439), and then they determine the topic of the research lesson using various materials. By developing a unit to investigate, they write a research lesson plan and deliver it while being observed. After debriefing based on their observation, they should report what they are doing lesson study to share their findings with other colleagues.

Fernandez et al. (2003) completed a lesson study of American teachers collaborating with Japanese teachers. Sixteen teachers and administrators participated in this study. The Japanese teachers facilitated the lesson study for American teachers to adopt and implement into their classrooms for the first time. Videotapes, field notes of meetings and lessons, products of lessons, and interviews were collected as data and analyzed. Based on the interpretation of the

data, the researchers found several challenges in adopting a lesson study: developing "meaningful and testable hypotheses," choosing proper methods for "exploring these hypotheses," using the evidence to evaluate the research outcomes, and documenting the findings of research for generalization (p. 173). They also informed concerns of Japanese teachers for adopting Japanese lesson study in American context. First, more interest and consistent effort to develop the curriculum are needed (p. 177). Next, a deeper understanding and investigation of student outcome is also needed (p. 179). Overall, they concluded that a lesson study was a beneficial and effective opportunity for American teachers to think about their teaching and students' learning in order to change their perspectives.

Similar to the previous study, Perry and Lewis (2008) conducted a four-year lesson study. They focused on how lesson studies worked and were adopted at the district level. A California K-8 school district participated in the lesson study from 2000 to 2004. "Interviews of approximately 70 teachers and administrators," observations, audio and video tapes, and "artifacts of lesson study practice" of about 20 lesson study groups were regarded as the data of this study (p. 4). Teachers had learned about the lesson study through various activities: "school year participation, workshops, public lessons, and other events" (p. 5). They changed the point of the lesson study from "an instructional product" to "a process of instructional movement" with additional impact: more reflection and feedback, a clearer understanding of "protocols and tools," more resources of "external knowledge," and more attention to "student thinking" (p. 7). Thus, it showed the possibility of adopting a lesson study in an American public schooling at the district level. However, better understanding of lesson studies, constructing teachers' professional learning communities, and distribution of teacher leadership would have improved the lesson study.

Overall, implementing lesson study in the US context has been attempted by many researchers with practical guidelines and positive efforts. Thanks to these trials, it became especially well known in the context of professional development through Wiburg and Brown (2006) because of "a 5-year professional development grant from the US Department of Education, 1999-2004" (p. 4). Currently, "140 Lesson Study groups" endeavor actively "in 29 U.S.A. states" (Takahashi, 2007, p. 194).

The types of research lessons in Japanese lesson study. Lewis (2000) addresses "types of research lessons" in her article (p. 6). The first type is "within-school research lesson" (p. 6). This type of lesson is natural for elementary school teachers, and therefore common. Teachers have learned through repeated experiences with lesson study with support from the administration in the school building. They focus on improving teaching according to the school goals. In other words, it is "in-school training" (Baba, 2007, p. 6). Similarly, Fernandez and Yoshida (2004) state that generally, lesson study is conducted as "in-school training" (p. 9) as the most common format of lesson study. Teachers in the same school setting use lesson study to create "an annual pedagogical theme" (p. 6) and structure teams for each grade and subject. This format enables teachers to develop trusting relationships and to maintain authority in the classroom.

The second type of research lesson is "public research lesson" (Lewis, 2000, p.7). It tends to be open to not only outside teachers from the school, but also higher educators from universities, supervisors of educational boards, or other educators who are interested in improving teaching and learning. It occurs especially when schools are given big grants to improve particular areas such as computer instruction or advanced international studies. Numerous educators visit schools and observe lessons, receiving all the materials related to the

lessons taught. This might also be a "voluntary group" supported by a "teachers' union and academic societies" (Baba, 2007, p. 6). It fosters a high quality of teaching and learning. Lastly, the third type of research lesson is "research lesson as part of national conferences, teachers' circles, etc" (Lewis, 2000, p. 8). This type of lesson encourages teachers and educators to observe the teaching of others in order to acquire improved knowledge of instruction and a better understanding of student learning. In addition, they participate in other government or university research and professional development using lesson study; even pre-service teachers and novice teachers experience lesson study with mentors (Fernandez & Yoshida, 2004). In a broader sense, Hattori (2007) mentions that lesson study refers to "a process by which teachers of mathematics at several schools in the same community work together to research teaching materials, develop teaching plans (lesson plan) and practice teaching lessons" (p. 228).

In conclusion, all three types of research lesson have been used for creating a natural learning culture of teachers and educators to improve teaching quality (Baba, 2007). These three types also enable teachers and educators to think about school wide goals to teach effectively and to improve instruction based on inquiry (Fernandez & Yoshida, 2004).

The emerging misconceptions of lesson study in the U.S. context. Misconceptions are described by Chokshi and Fernandez (2004). For example, there is the idea that a lesson study is a process of "creating" (p. 522) a quite new lesson, and focusing on only a few lessons. Some people also believe that lesson study requires a perfect single lesson, as Lewis (2002) mentioned, and whole files of lessons, "producing a library" (p. 523). Others think that lesson study focuses on one single objective, specifically one lesson and one objective at a time. From a similar standpoint, Lewis (2002) pointed out more misconceptions of lesson study: it is "lesson planning" (p. 83); it is about collecting scratch ideas from groups and writing about it; it requires "a rigid

script" (p. 84); it is just an exhibition of lessons from experts; and it is "basic research" (p. 86). Chokshi and Fernandez (2004) addressed possible solutions for the aforementioned challenges, and Lewis (2002) offered many explanations to rectify these misconceptions. These explanations will be addressed in the next sub-section.

Misconceptions of lesson study set straight. Above, some "common concerns and assumptions" of lesson study were introduced, based on the work of Chokshi and Fernandez; they also mention the truth of lesson study. It is in fact possible to implement lesson study in other countries (e.g., America, Korea or South Africa, Isoda et al., 2007), since there are many common perspectives in terms of teacher learning and growth (Fernandez & Yoshida, 2004). In addition, American teachers would have time to collaborate for lesson study with administrative support, and although there is not much evidence about how lesson study impacts students' standardized tests yet, lesson study can provide evidence of student learning based on the collection of data from students' artifacts. Teacher's content knowledge was a concern, but since lesson study offers opportunities for teachers to acquire content and instructional knowledge (Lewis, Perry, & Friedkin, 2009), teachers are able to increase their knowledge through lesson study. Finally, lesson study guides mentoring and collaborating in a comfortable environment, especially for novice and pre-service teachers. Table 4 shows the corrections to the misconceptions about lesson study, based on the work of Chokshi and Fernandez (2004) and Lewis (2002).

Table 1

Accurate Conceptions of Lesson Study

	Misconceptions	Accurate conceptions
Chokshi and Fernandez (2004)	"Creating" (p. 522) a quite new lesson Focusing on only few lessons A perfect single lesson "Producing a library" (p. 523)	Developing relative lessons Focusing on continuum practice of lesson study Rather improved and qualified lessons "Engaging in the intellectual process" (p. 523)
Lewis (2002)	" Being lesson planning" (p. 83) Collecting scratch ideas "A rigid script" (p. 84) A perfect lesson Exhibition of lessons from experts "Basic research" (p. 86)	A broader and bigger process Integrating teaching ideas to practical student learning More careful and flowing instructions Potentially applicable lessons Equal contribution from all participant Research on continuous improvement of teaching with active efforts

Suggestions for overcoming the challenges of importing lesson study. Much of the recent literature surrounding lesson study suggests practical recommendations for understanding lesson study and conducting it within any school setting. First, teachers need to have a necessary and proper curriculum (Lewis, 2002; Fernandez et al., 2003), and they need to have access to all the materials they want for conveying a well qualified curriculum to students (Fernandez, 2002). Next, they need to have an open mind for reflection on their own teaching (Lewis, 2002; Fernandez & Yoshida, 2004), and they need to focus on student learning and anticipation of their thoughts, as well as "learn" how to observe (Chokshi & Fernandez, 2004, p. 38).

More importantly, the acceptance of different opinions from people outside the classroom is needed (Chokshi & Fernandez, 2004; Lewis, 2002). This attitude can be established by developing "a culture" of lesson study (Watanabe, 2002, p. 38), having a disposition of writing lesson plans, examining curricula with a view to the unit, and supporting teachers' autonomy of teaching.

A willingness to make mistakes, flexibility in the implementation of lesson study (Lewis, 2002), and sufficient time (Stepanek et al., 2007) are also crucial points for guiding the

application of lesson studies to reduce barriers and limitations. Furthermore, more assessment of lesson study is needed for improving lesson study as a means of professional development (Stepanek et al., 2007).

Overall, it may be impossible to apply all these suggestions at the same time, but the gradual effort of changing and improving lesson study will affect teachers' professional learning culture (Fernandez, 2002). Thus lesson study will be integrated into teachers' learning communities in some form (e.g., "regional study group" or "teacher clubs", Fernandez & Yoshida, 2004, pp. 213–214; more widely "research schools", Lewis, Perry, Hurd, & O'Connell, 2006, p.281). Lesson study will assist the creation of a network among lesson study groups (Chokshi & Fernandez, 2004; Fernandez & Yoshida, 2004). To this end, principles and administrators of school buildings or districts should support teachers' completion of the lesson study with continuous professional development programs and school-based facilitation (Stepanek et al., 2007).

Potential benefits of lesson study. Although lesson study work is time-consuming, it allows, among other things, for teachers to have a clear idea of their strengths and weaknesses (Fernandez & Yoshida, 2004), and enables them to be reflective on their teaching and students within a collaborative environment (Fernandez, 2005).

Lesson study also allows for them to gain vital information that can be used to improve their teaching skills (Fernandez & Yoshida, 2004). More specifically, it assists teachers to gain content knowledge and instructional knowledge, to increase the capability of observing students, to build strong mutual networking, and to connect long-term goals to practice with confidence in order to improve the quality of their lesson plans (Lewis et al., 2004). In addition, lesson study offers teachers the opportunity to discuss content with an open mind and a willingness to share

their experience (Fernandez, 2005; Fernandez & Yoshida, 2004). It also stimulates teachers to better understand students and to obtain pedagogical knowledge. This latter benefit is an emphasis of Japanese teachers regarding lesson study (Fernandez & Yoshida, 2004). .

Next, lesson study helps teachers make a connection between "educational goals and standards" and daily life in the classroom (Lewis, 2002; Takahashi & Yoshida, 2004). It facilitates teachers' discovery of goals for teaching and student learning, so it leads teachers to be more interested in classroom practice and motivates them to have a confident attitude for personal growth (Fernandez & Yoshida, 2004).

Finally, lesson study fosters data-driven teaching improvement and student-centered teaching for reaching many students (Lewis, 2002). Since lesson study focuses on student learning, teachers are able to observe students' thinking and learning (Fernandez, 2005). Takahashi and Yoshida (2004) claim that it enables teachers to "learn to see their practice for the child's perspective" (p. 438). In addition, lesson study facilitates the construction of "grassroots" teaching improvement and fosters effective teaching for the improvement of student learning (Lewis, 2002).

Key elements of lesson study related to continuity. As mentioned in Chapter 1, sustainability is "a broad term that incorporates essential notions in continuation" (p. 92), and does not mean "institutionalization" and "routinization" (Shediac-Rizkallah & Bone, 1998, p. 93). Also, it "is the capacity of programs to continuously respond to community issues" (Mancini & Marek, 2004, p. 339). To measure sustainability, several elements are necessary: leadership ability, effective collaboration, community understanding, beneficial program results, efficient funding, integration and involvement of staff, and program responsibility (p. 340).

Researchers examined key elements of lesson study related to sustainability in order to know what makes lesson study sustainable. First of all, the cycle of lesson study itself is one of the key elements related to sustainability (Lewis, 2002). Since the cycle includes the sustainable process of lesson study (including. planning, first delivering, debriefing, second delivering, and another cycle of same process), it provides continuous loops in order to consider the connection of the long-term goals to a research lesson, allows participants to develop a well organized lesson plan based on the anticipation of students' performance and to revise the lesson with feedback and reflection via observations of delivering the lesson, and provides open-minded and flexible collaboration with peers.

Second, the role of facilitators (or lesson study team members) is another key element of sustainable lesson study because lesson study contributes to a shared professional culture instead of professional activities (Watanabe, 2002). In order to share professional culture, facilitators should know what lesson study is about precisely, have experience with lesson study through various activities (e.g. workshops, practical experience, resources, multi-media etc), be aware of the challenges and complexity of lesson study, seek the possibility of importing lesson study into a different culture with minimum conflicts, and provide support for a certain duration until participants fully understand what lesson is about and know the benefits of it through the real experience of lesson study.

Lastly, an opportunity for disseminating lesson study and constructing lesson study communities is the last key element of lesson study (Perry & Lewis, 2008). Lesson study is not often heard about because it is a new approach to professional development in the US context. As a result, more opportunities for introducing lesson study are needed. Although there are several lesson study research teams in the US, more teams are needed to build lessons study

communities. Once, lesson study is established and adapted into the US culture, it empowers participants to continue lesson study in educational settings.

Summary

Consistent and well-organized support is needed through structured professional development for in-service teachers to acquire knowledge through the daily experience of teaching. This includes building and structuring knowledge as a craft, reflection on teaching, and inquiry into practice (Cochran-Smith & Lytle, 1999). Well-supported teachers can play a critical role in developing "knowledge-in-practice" (Cochran-Smith & Lytle, 1999. p. 250; Fernandez, 2002; Lewis et al., 2004), regarding students' learning process based on inquiry.

Although lesson study work is time-consuming, it allows, among other things, for teachers to have a clear idea of their strengths and weaknesses (Fernandez & Yoshida, 2004), and enables them to be reflective on their teaching and students within collaborative environments (Fernandez, 2005).

Lesson study also allows teachers to gain vital information that can be used to improve their teaching skills (Fernandez & Yoshida, 2004). It offers teachers the opportunity to discuss content with an open mind and a willingness to share their experience (Fernandez, 2005; Fernandez & Yoshida, 2004). It helps teachers make a connection between "educational goals and standards" and daily life in the classroom (Lewis, 2002; Takahashi & Yoshida, 2004). Finally, lesson study fosters data-driven teaching improvement and student-centered teaching in order to reach many students (Lewis, 2002).

Overall, the gradual effort of changing and improving lesson study affects teachers' professional learning culture (Fernandez, 2002). Thus, lesson study is integrated into teachers'

learning communities in some form (e.g., “regional study group” or “teacher clubs”, Fernandez & Yoshida, 2004, pp. 213–214; more widely “research schools”, Lewis et al., 2006, p.281). Lesson study helps create a network among lesson study groups (Chokshi & Fernandez, 2004; Fernandez & Yoshida, 2004). In order to do so, principals and administrators of schools or districts should support teachers’ completion of lesson studies with continuous professional development programs and school-based facilitation (Stepanek et al., 2007).

Chapter 3

Method

Introduction

This study was conducted using qualitative methods, because qualitative evidence has the potential to shed light on the implementation of lesson study without funding support. Interviews, participant and non-participant observations, open ended surveys, and detailed vignettes were the main tools of data collection. Relevant artifacts were also collected as necessary.

This study intended to support lesson study as a method of professional development for high school teachers, which would affect teacher practice. To explore the implementation of lesson study, the following questions were investigated:

> How did teachers in a high school setting who had experienced lesson study before implement their work after the funding for their lesson study had ceased?
>
> 1. What did teachers do independently to implement lesson study?
> 2. What kinds of support did teachers need to implement lesson study?
> 3. What were benefits for teachers?
> 4. What were challenges for teachers?
> 5. In what ways, if any, could lesson study be continued?

As mentioned in Chapter One, the purpose of this study was to examine and elucidate the implementation of lesson study as a method of professional development after the initial funding had ceased in high school mathematics and science settings. In light of Fernandez's (2005) description of the future direction of lesson study, this study considered what teachers obtain through the lesson study process, besides increased knowledge of content and teaching. It

examined teacher practice with support for lesson study groups. Lewis et al. (2009) provide more detail about areas that need to be studied; this study focused on several dimensions of the implementation of lesson study (actual implementation, practical support, benefits, challenges, and possible continuity).

Research Design and Rationale

A case study allows deeper interpretations and explanations of the complexity of a unique case (Stake, 1995). It provides more interest in the process instead of outcomes, so it expands the researcher's insight into the case (Merriam, 1998). Hence, this project was implemented as a case study, since this study focused on: the implementation of lesson study within a unique high school setting; the process of lesson study as a method of professional development, with special teachers who have previously experienced lesson study, after the end of funding from a university partnership; and the possibility of expanding teachers' points of view about teaching and learning through lesson study.

I facilitated the implementation of lesson study with two groups in a high school: a mathematics group and a science group. The teachers conducted one cycle of lesson study based in their previous two-year experience with lesson study which focused on improving their instruction and anticipating student performance as a method of professional development. The process of the lesson study was carefully investigated collaboratively with teachers. The teachers and I worked to fully understand what lesson study was as an activity of professional development. Teachers in each group selected a chapter for which they wanted to improve their instruction with the aid of technology if it was necessary, and they discussed the overview of the lesson study process related to their school improvement goals and their personal overarching

goals of teaching. After discussion, each group chose a research lesson with specific objectives to explore based on students' struggles with learning or teachers' challenges in teaching mathematics and science. They examined their mathematics or science curriculum (e.g., the *Discovering Algebra* textbook or *CPM Geometry*), which was based on inquiry principles and was aligned with the content required in the Illinois Learning Standards. Then they worked to integrate technology with textbook activities connected to students' interests and the efficiency of delivering the teaching objectives in mathematics and science. Finally, they created a timeline including planning the lesson, delivering the lesson and debriefing it, and re-teaching the revised lesson based on their discussion in order to apply the lesson study to their classroom during the 2009 school year.

The teachers involved in the lesson study met at least four times during the semester when they implemented lesson study, and the lesson study process consisted of four phases: planning the lesson, teaching the lesson and observing teaching, discussing observations and reflections, and re-teaching a revised lesson and debriefing on it. There was more than one meeting for planning the lesson prior to teachers implementing it with their students. The teachers and I developed a lesson plan according to the students' interests and the teachers' concerns. During this planning time, teachers discussed how to deliver the lesson effectively so their students could understand the mathematics and science concepts and how to use the necessary technology. The teachers and I outlined the lesson and wrote details of instruction in anticipation of students' thought processes and responses.

Next, while one of the teachers taught the lesson with his/her students, the other teachers and I observed both the teacher's instructions based on the written lesson plan including specific observation objectives and the students' thought processes, revealing how they express their

ideas about mathematics and science through the new piece of technology. During the observations, observers did not interrupt student learning or the teacher's teaching because lesson study respects the natural teaching and learning occurring in the classroom.

A debriefing session including all participants was crucial for teachers to reflect on their teaching and to expand their understanding of student learning. They revised the lesson based on their observations and feedback. After discussion, another teacher from each group taught the improved lesson in a different classroom setting. While s/he was doing so, the others observed the classroom again with a focus on whether the changes worked or not. Finally, they shared what they learned through the lesson study, considering what had worked and what had not.

The expectations of the lesson study for mathematics and science teachers included both the teacher's and students' perspectives. The possible benefits for teachers were improved mathematical or scientific content knowledge, including the confirmation of existing knowledge; improvement of instructional knowledge, using the technology for their current mathematics or science curriculum, rather than developing a new curriculum to use; and support for continuous growth through lesson study experience. Possible benefits for their students were improved achievement on the mathematics or science concepts, a better understanding of how to collaborate with others while using technology, and more engagement in mathematics and science lessons because of their teachers' improved instruction.

Participants and Site

Site of the study. The high school where this study was implemented was an urban school in the Midwest. It had approximately 2,100 students from 9^{th} to 12^{th} grade, and 105 teachers, including 14 mathematics and 15 science teachers. The students at this school had

become more diverse in recent years: the population of Hispanic students had increased 22% since 2004, and the population of African American students had increased 74%. However, the population of Asian and Pacific Islander students had decreased 40%. The majority of students were white and most of the mathematics and science teachers were white as well. The school had 13 different mathematics classes, including Algebra I, Algebra II, AP Calculus, and Geometry; and 10 science classes, such as Fundamental Physical Science, Biology, Chemistry, Ecology, and Human Anatomy & Physiology.

The school's policy for professional development. According to the "Single School District Improvement Plan 2008," the following strategies and activities were executed for the school.

1. View Harrisburg Video for the data entry and the teachers. Teachers have been in-serviced on EASY IEP and will continue to receive during the school year.
2. Purchasing of Career Cruising to help as a tool to assist in age appropriate transition assessment and student career planning.
3. Provide staff with instruction on developing measurable post high school goals which will include oral presentation with Power Point and handouts.
4. Provide teaching staff with checklist to meet SPP/ARP requirements for Indicator 13 in both paper and electronic form.
5. Provide staff with resources provided by ISBE at http://www.isbe.net/spec-ed.
6. Additional training for all teachers in the three major topics – assessment, curriculum design, and research based instructional strategies for struggling students.
7. Train staff in Project CRISS and other reading comprehension strategies.
8. Collaborate with the university to provide strategies for at-risk learners.
9. Provide staff development in technology and curricular integration.
10. Provide professional development for teachers in interpreting and using MAP results and other date points to improve student achievement.

11. Provide teachers with training in models of differentiated instruction.
12. Educate staff regarding Rtl concepts and implementation strategies.
13. Discuss and develop with staff behavioral expectations for class attendance, tardy, and homework.
14. Complete Parent Involvement Analysis Tool and report results to staff. Solicit suggestions for improvement. (The Single School District Improvement Plan 2008, p. 21)

The school goals for the 2008 school year included curriculum alignment, assessment revision, and instructional improvement. Professional development was slated to assist teachers in adapting new textbooks, participating in workshops or conferences, working with colleagues, and revising their pedagogy. Specifically, the goal of the professional development program was to improve and develop instructional skill and knowledge in order to enhance achievement and maintain high level performance. There was more than one instance of staff development in this school. Teachers attended programs for training on current practice, fulfilling their needs of confusion on teaching and learning, and providing suitable information for the school context.

Evaluation process. There were three different stages of the evaluation process: Track I, Track II, and Track III. Track I comprised the first four years of teaching employment, during which teachers needed to show an understanding of the standards and an ability to apply content knowledge. After successful completion of Track I, they moved on to Track II, during which, they were expected to demonstrate their professional growth. Finally, Track III helped teachers improve their teaching effectiveness With the guidance of administrators, teachers were required to engage in some form professional improvement, which they could complete individually.

Participants of the study.

Recruiting procedures. I contacted mathematics and science teachers who had had experience with lesson study through the university partnership from 2007 to 2008 school year,

because I wanted to investigate how they could implement lesson study independently after the initial funding had ceased. In the summer of 2008, I emailed them individually a detailed explanation of the study to see if they were interested in participating. Some of them replied with positively, but some of them were not interested in lesson study either because they had come away from their previous experience with a negative impression of the time commitment lesson study involved, or due to other challenges. For instance, one math teacher anticipated a busy 2009 school year because she was changing subjects, and one science teacher viewed lesson study as time consuming, too narrowly focused on a specific lesson, and requiring much writing. Other teachers had formed positive impressions of lesson study and were willing to participate in this study, despite the lack of funding. Also, their Track II Evaluation Project, as described above, was a motivating factor for their participation in this study. In addition, one of the teachers mentioned the rapport between the teachers and me as a reason for participating in this study.

After the email recruitment, I visited the first mathematics and science department meetings of fall 2008 and confirmed who would be participating in this study. We discussed a tentative schedule for conducting the lesson study and got signatures from them to confirm their participation. The actual participants in this study are described below in detail.

Teachers. The main participants of this case study were three experienced high school mathematics teachers, two science teachers, one special education teacher, and one reading coordinator. The teachers were selected based on their interest in lesson study, as well as their previous experience with lesson study. They were recruited through an announcement of the university partnership via several different contacts with the staff of the university, as well as a previous coordinator and administrators from their high school. I asked them to participate in this study based on a positive relationship I had with them. Most of the participants had experienced

lesson study for at least two years from the 2007 to 2008 school year. They expected to obtain more effective ways to implement a rich lesson plan according to the students' mathematics or science curriculum needs. They had various levels of experience teaching high school students, from novice to veteran (ranging from six to 25 years of experience). Some of their strongest personality traits were a willingness to improve their instruction and learn about using technology in different ways, and an enthusiasm for teaching.

Coordinator of the school. The coordinator of the school had had experience with the university partnership. She had been willing to introduce the partnership to her school and had put forth enormous effort to encourage the teachers' participation in all activities provided by the university. As a result, the teachers had adopted new textbooks in mathematics and science education. She was invited to this study for her perspective on developing a professional development program for her school.

Facilitators of the university partnership. There were several facilitators, and their responsibilities included recruiting teachers as participants, preparing summer and follow-up workshops, supporting teachers consistently during the school year, and developing the professional development program itself. Two of the facilitators already knew the superintendent and the curriculum coordinator, and they asked the superintendent for permission to meet with teachers and introduce the university partnership to them. Therefore, most teachers were recruited through the facilitators and the curriculum coordinator. They were invited to this study for their experience with professional development programs in the high school setting.

As mentioned earlier, facilitators provided support for participants whenever they needed help. Thus, they communicated with participants by email and telephone, and also made personal visits to their classrooms. They also provided practical assistance based on their 35+ years of

teaching experience and helped participants use technology in their classrooms during the school year. Whenever the teachers had problems using technology, facilitators worked with them. They also had presented activities and lectures during previous summer workshops.

Data Collection

Stake (1995) addressed important questions about the planning of data collection: "What needs to be known? What are some possible relationships that may be discovered?" (p. 54). I wanted to know how high school math and science teachers would implement lesson study without funding. To explore this question, I included two different sets of data. The primary source was the data from Fall 2008 and Spring 2009 from the participants and site outlined above.

The secondary source was the previously collected data, from the lesson study that ran during the 2007-2008 school year, and was sponsored by the university partnership. It consisted of audio recordings of the lesson study, including planning meetings and the delivery and debriefing of lessons; and artifacts, such as lesson plans, observation forms, surveys, and emails among teachers and facilitators concerning the lesson study.

In Fall 2008, the group of math teachers participating in this case study implemented lesson study once in their classroom. There were two planning meetings prior to their teaching and one of the teachers delivered the lesson as the first trial. Following the lesson, all members of the math group gathered and discussed what had gone well and what needed improvement based on their observations. After the first trial, another teacher delivered the same lesson again with modifications as the second trial. Finally, all of the members gathered again and discussed the whole procedure and their observations and thoughts.

In Spring 2009, the science group implemented lesson study as well. There were several planning meetings due to a change of research lesson topic. One of the group members delivered the lesson and all members debriefed the lesson. With some revision of the lesson, another teacher taught the lesson. Following the second trial, all teachers in the science group discussed what they had observed and what they thought about the lesson study during the second debriefing.

All teachers were given pre- and post-project interviews to assess their understanding of lesson study and the efficacy of lesson study as a method of professional development. Each interview was approximately 10 to 30 minutes long, depending on how they answered the interview questions. The coordinator was given one interview to ascertain what kinds of support for lesson study had been provided when funding had been available and what they thought about lesson study. Facilitators from the university were not given interviews because they had been interviewed previously.

The teacher participants were requested to complete a survey as soon as they completed the lesson study about what they thought about the lesson study, what kinds of benefits and challenges they had faced during the implementation of the lesson study, and the impact of the lesson study on their teaching. Any e-mails between with me and the participants were stored on a secure, password-protected computer hard drive after collection.

Importantly, permission letters were distributed to students and their parents in order to ask their permission to be observed in their classrooms without the interruption of their natural learning environment. Also, permission was requested of math and science teachers who did not participate in this case study to observe their department meetings, so that I could compare these meetings to the lesson study planning meetings.

These data provided triangulated information about the possible sustainability of lesson study, and the implications for education. More detail about the analysis of the data in terms of the research questions will be presented in Chapter 4.

Data Collection Strategies and Sources

The qualitative data collection in this case study follows Stake's (1995) case study procedure and involves a description of the context, observations, and interviews. The context consists of the school setting and the participants of the case study, as described above. Next, observations were completed from two perspectives: participant observation and non-participant observation. The observation of the lesson delivery in the teachers' regular mathematics and science classes constituted non-participant observation, and this perspective afforded the observer some distance from the teacher and students, which allowed for the collection of objective data in order to understand what went on in the teachers' regular teaching. On the other hand, participant observation occurred when the teachers implemented the lesson study while the facilitator assisted teachers in planning the research lesson and debriefing. Two interviews were given to each participant: one before and one after the lesson study.

Additional data included teacher documentation of lesson planning, reflections from the debriefing, a feedback survey, and my field notes, all collected in order to understand the complexity and uniqueness of this case study. Finally, student outcomes were valuable as further evidence of the teachers' instructional improvement and understanding of their students' grasp of the concepts presented in the research lesson. Artifacts from the students in the classroom were collected as necessary.

Secondary sources. To understand the nature of lesson study in this high school mathematics and science setting, a secondary source--the data previously collected from the funded lesson study supported by the partnership with the university was examined. The secondary source data was collected during the 2007-2008 school year and consisted of audio recordings of the lesson study, including planning meetings and the delivery and debriefing of lessons; and artifacts, such as lesson plans, observation forms, surveys, and emails among teachers and facilitators concerning the lesson study. These data provided evidence of what kinds of experiences participants had had over the previous two years.

Also, to understand the general idea behind constructing a professional development program for this high school, the secondary source included data collected from previous summer workshops from 2006 to 2008 sponsored by funding and a partnership with the university. The data includes audio and video recordings of workshops, pictures of activities, handouts, interviews with a facilitator and teachers, and artifacts such as surveys and yearly reports of the program.

Observations. For this case study, participant and non-participant observations were performed. As Bogdan and Biklen suggested (2007), participant observation allows researchers to "know the subjects through interacting with them" (p.95). The level of participation had been determined by the degree to which the researcher was needed as an expert and helper for the teachers while conducting the lesson study. Therefore participant observation was performed in order to understand how teachers conducted lesson study and what kinds of help they needed from me.

When the math group implemented lesson study during the fall of 2008, a total of three 60-minute participant observations and one 120-minute participant observation of two planning

meetings and two debriefing meetings were conducted. Compared to the math group, the science group had more frequent but shorter planning meetings and spent the same time in debriefing meetings during the spring of 2009. The purpose of these participant observations of lesson study were to collect evidence that assisted in understanding the process of lesson study implementation in the high school mathematics and science classrooms.

Non-participant observation entails that the observer remains unobtrusive during the observation and has no involvement with those observed (e.g. Bogdan & Biklen, 2007; Merriam, 1998). Hence, as a researcher of this study, I took detailed notes and remained relatively passive throughout the lesson delivery in the mathematics and science classroom observations. By documenting classroom activities and students' responses to teachers during the lesson delivery, the objective of the classroom observations was to obtain an understanding of teachers' instruction and interactions with students related to their intentions and concerns in order to improve their teaching. These observations included a focus on "finding good moments to reveal the unique complexity of the case" (Stake, 1995, p. 63).

Also, six 50-minute non-participant observations were performed during the lesson delivery and during the teachers' regular mathematics and science classes during the fall of 2008 and the spring of 2009. The first three classes were chosen before lesson study implementation in order to obtain an idea of how the teachers teach mathematics and science concepts in their regular classes. The last three classes were chosen after lesson study implementation because of their relevance to the unit that lesson study was implemented in. The purpose was to recognize similarities and distinctions in their classroom instruction as compared to the lesson they developed collaboratively.

Seven non-participant observations were performed at the mathematics and science department meetings during the Fall 2008 and Spring 2009 semesters (three times for math and four times for science). These observations showed the nature of a professional community in a high school setting, and they provided a general notion of how teachers collaborate based on their discussion of issues, challenges, concerns, and other matters of teaching and learning. They also alerted me to any issues, concerns, or challenges teachers had for their teaching and so that I could compare these patterns with the implementation of the lesson study procedure.

Interviews. In-depth interviews were crucial for this case study. Kvale and Brinkmann (2009) claim that "qualitative interviews can contain detailed descriptions of the subjects' life situations, their experiences, and actions" (p. 271). Hence, in-depth interviews allowed me to understand the teachers' experiences, concerns, expectations, benefits, and challenges of conducting lesson study in their mathematics and science classrooms. They also revealed their over arching goals of teaching and their understanding of what lesson study was.

According to Kvale and Brinkmann, there are 10 important interviewer qualifications. They should be "knowledgeable," "structuring," "clear," "gentle," "sensitive," "open," "steering," "critical," "remembering," and "interpreting" (2009, pp. 166-167). When I conducted the interviews, I respected the interviewees' viewpoints, kept an open mind, and was able to build a comfortable interview atmosphere based on previous interaction, which allowed them to comfortably express themselves. I prepared the interview questions with their previous statements in mind and responded to their answers sensitively and gently. Therefore, the interviews went very smoothly.

A researcher should be able to develop a view of their interviewees' understanding of some part of the world through the interviews as a data collection tool (Bogdan & Bikilen, 2007).

Indeed, I was able to glean some insight into how the teachers had attempted to make connections between lesson study and their teaching and how they had done their best to follow the procedures of lesson study.

Pre- and post-project interviews were conducted, each lasting from 10 to 30 minutes and including approximately 10 questions. Some of the questions were very similar on the pre- and post-project interviews, while some of the post-questions were quite different, based on what the teachers had mentioned in their pre-project interviews and on my observations. The interview questions were related to the teachers' experience with lesson study, their intentions for teaching concerning student learning, their reflections on collaboration through lesson study, and their expectations of implementing lesson study. All interviews were audio taped and transcribed for data analysis.

The pre-project interview focused on participants' experiences with lesson study during the previous year with funding and their general ideas about professional development. The interview questions addressed lesson study itself, the professional development program in which they had been involved, and, more superficially, mathematics or science teaching and learning.

The post-interview focused on their experiences with lesson study for the current year without funding and their reflections on implementing lesson study. The interview questions addressed help from the facilitator, changes in instruction, sustainability of lesson study, understanding of lesson study, and implications for future teaching.

Teachers' documents and reflections on lesson study. Recently, qualitative research has emphasized the importance of document data besides observations and interviews (Bogdan & Biklen, 2007). Based on this emphasis, this study included teachers' documents written for

lesson study in order to reveal teachers' understanding of lesson study. Bogdan and Biklen (2007) defined relevant documents as "official documents produced by organizational employees for record-keeping and dissemination purpose" (p. 64). Following this definition, all official documents of lesson study were collected and analyzed in this study. The teachers' documentation of lesson plans, observation templates for lesson study, lesson materials, feedback, and transcriptions of discussions were collected to more fully understand teachers' concerns, issues, and challenges regarding lesson study.

Besides these documents, teachers' reflections during debriefing were audio taped, because they constituted very important data regarding the purpose of lesson study. One of the purposes of lesson study is that teachers can evaluate their teaching through their own reflections. Therefore, they should collaborate and interact as much as possible to provide beneficial lessons for students.

Teachers' reflections took place when teachers debriefed the research lesson. They reflected on their teaching and expanded their understanding of student learning. They revised the lesson based on their feedback. Finally, they shared what they had learned through the lesson study, considering what went well and did not work.

Open-ended survey. After conducting the lesson study, one open-ended paper survey was given to teachers. This survey allowed a deeper insight into teachers' thoughts on lesson study and their actual understanding of the concept of lesson study. Also, it showed what assistance from me had been beneficial. The following set of questions served as a guide:

1. What was your focus during your observation of the first lesson?
2. What was your suggestion for the second lesson during the debriefing?
3. What was your focus during your observation of the second lesson?

4. Compare and contrast the first and the second lessons.
5. What would be possible applications from the first and second lessons to your own classroom?
6. What did you learn through this lesson study process?
7. What, if any, were your challenges in implementing this lesson study?
8. What are your concerns about your next lesson study, if you choose to do one in the near future?

Field notes. Field notes contain "ideas, strategies, reflections, and hunches" based on what the researcher hears, sees, experiences, and thinks, and they serve as data in a qualitative study (Bogdan & Biklen, 2007, p. 118). I wrote field notes while assisting the lesson study, and also during my observations of lesson delivery and the teachers' regular mathematics and science classrooms. The field notes described what was successful or complicated when the lesson study was implemented, identified the teachers' "aha" moments about student learning, described what had been discussed with the teachers, and pointed out what was needed for subsequent steps.

Student artifacts. Young and Lee (2005) found that "high-quality materials and intensive teacher professional development in science" facilitated students' science learning (p. 480). High quality teacher performance in practical classes enables students to reach a higher level of achievement. (Huffman, Thomas, & Lawrenz, 2003). Hence, student artifacts can be used as evidence for whether the teachers have improved their instructional knowledge, since the students' work demonstrates their learning processes and their content knowledge. As mentioned previously, student work was collected as necessary. For example, during the science lesson study, students showed their understanding of science content based on reading guides as a group activity on the board. Their answers provided information about what they thought about the content and what they needed to improve on. Therefore, student work was collected as data.

Data Analysis

"The qualitative researcher concentrates on the instance, trying to pull it apart and put it back together again more meaningfully--analysis and synthesis in direct interpretation" (Stake, 1995, p. 75). Bogdan and Biklen (2007) explained that data analysis and data interpretation were comprised of collecting, organizing, breaking into reasonable pieces, coding, and synthesizing data. Interpretation means to develop ideas based on findings and to make connections between ideas and the literature in order to make your findings valuable. Among the different approaches to data analysis, content analysis was employed for this study since it is a part of textual analysis, including comparison, contrast, and categorization of data, and also including the making, applying, checking, categorizing, and analyzing of data with interpretation (Schwandt, 2001). Thus there were several phases of data analysis for this study according to the "categorical aggregation or direct interpretation (Stake, 1995, p. 77).

Phase I. The purpose of Phase I was to identify of the participants' experience with lesson study and support from the previous partnership, and their expectations of lesson study. In addition, identifying participants' teaching activities in their regular classroom was another purpose of Phase I, in order to understand their characteristics, their teaching styles, and the contexts of their classrooms.

For these purposes, pre-project interviews and observations of participants' regular teaching were collected. As Miles and Huberman (1994) suggested, the interviews were transcribed and analyzed, focusing on teachers' experiences and ideas about lesson study and the support of the funded professional development program. The transcriptions of the interviews were reviewed several times and organized into categories so that each individual's opinion could be included.

Based on the interviews, participants exhibited positive impressions of lesson study (e.g. it was beneficial for improving lessons, collaboration, etc.) and positive expectations for conducting future lesson study, such as obtaining different perspectives from peers, specific observations of student performance, more feedback on teaching, and collaboration with colleagues. They needed practical and specific guidance in order to implement lesson study, detailed and sufficient explanation of the different roles involved, and descriptions of the lesson study procedures.

In addition, the observations highlighted teachers' instruction and interaction with students. The observation revealed teachers' classroom management styles (e.g. strongly organized vs. flexible management) and general instruction style (e.g. lecture, small group work, etc.). Miles and Huberman (1994) defined a vignette as "a focused description of a series of events taken to be representative, typical, or emblematic in the case you are doing" (p.81), so vignettes were included to show "a-ha" moments and emerging issues during instruction. Observations also provided insights into student performance (e.g. asking questions, answering, discussion, lab activities etc), and teachers' specific interactions with students (e.g. questioning, guiding etc).

Phase II. The main focus of Phase II was to determine how participants implemented the lesson study. In other words, the lesson study procedure was spotlighted for Phase II: what kind of help from the facilitator was needed, and teachers' basic ideas about teaching in terms of overarching goals and expectations about student performance. To determine how participants implemented lesson study, observations, field notes, and open-ended survey were collected. These data were analyzed by coding and categorizing the content.

Observations of the lesson study were categorized by purpose, content, and issues. For example, for the planning time, there were several purposes, including scheduling and choosing a topic for the first session, and, for the second session, confirming the research theme and observation focus, completing the planning of the research lesson, and discussing the preparation of materials for delivering the research lesson. Overall, the contributions of the participants and what I contributed was illustrated by observation analysis.

The field notes were analyzed by categorizing and comparing the participants' collaboration and the interaction between the participants and me. Also, the kind of assistance that was beneficial for participants was evaluated. The kinds of help I provided included lesson study materials, lesson study protocols, scheduling and bridging, and checking teachers. As participants had needed very detailed lesson study protocols in Phase I (e.g. a sufficient explanation of the process of lesson study, specific directions for the steps of lesson study, details of roles, help planning the research lesson, and keeping track of the steps of the lesson study), I guided them to understand what lesson study is and what procedures it included.

Finally, the open-ended survey was analyzed in order to determine the benefits and challenges of implementing lesson study. Participants listed as benefits of the lesson study the acquisition of more comments on their teaching, collaboration with other teachers, and the opportunity to consider student performance closely via observation. Teachers listed as challenges: finding time, unfamiliarity with the procedures of lesson study, and interruption of student learning during observation.

Phase III. Assessing the possibility of continued lesson study without funding was the purpose of Phase III. For this purpose, the participants' teaching was observed again in order to explore any changes resulting from lesson study. For the most part, their instructional skills and

knowledge were the targets of these observations (e.g. interaction with students, classroom management etc).

In addition, the observations of the math and science department meetings were analyzed for the possibility of conducting lesson study with a wide range of implementation. Department meetings were compared with lesson study in terms of frequency, agenda, duration, purpose, and activities to reveal similar elements. Last, post- project interviews with participants were conducted with a focus on their opinion of continuing lesson study without funding.

Observations of teachers' instruction after lesson study implementation showed that they had learned how to observe student performance and improve their instructional strategies based on their observations, to make connections between their teaching goals and their teaching, and to collaborate with other teachers naturally. Also, department meetings were similar to lesson study in their discussion of the content of teaching, pedagogical knowledge, student performance, and teaching focus and goals.

Participants confirmed their views on lesson study through the post-interview. Some emphasized the potential of lesson study to develop their teaching instruction, to focus their teaching on students more often, and to be able to continue with support from the school. In contrast, some teachers stressed that lesson study was time consuming and complex, and that they had insufficient experience with it.

Validity of Qualitative Research

Golafshani (2003) stated that "the concept of validity is described by a wide range of terms in qualitative studies" (p.602). There is no single definition of the concept of validity in qualitative research. This study employed Guba and Lincoln's (1985) four-part notion of validity:

credibility, transferability, dependability, and confirmability. Credibility concerns confidence in the truthfulness of the findings. Transferability concerns the possibility of applying the findings to various contexts. Dependability concerns the ability to repeat the findings consistently. Finally, confirmability concerns whether the findings are formed by the participants or the researchers, and deals with prejudice, inspiration, and awareness.

All three phases of data analysis provided valid evidence for this case study and were essential to the final assertions of this study. Once each piece of evidence was collected, the communication between the participants and me created another layer of credibility. I tried to look at the evidence from the participants' point of view in order to understand the context of this study. In addition, even though this study was not seeking a general finding for the implementation lesson study within a high school setting, I attempted to identify any findings that could be transferred to other contexts.

Moreover, lesson study has been implemented in various contexts; I used the same procedures that have been used in recent research on lesson study in order to enhance the dependability of this qualitative research. Finally, I attempted to provide member checking to resolve and negotiate any discrepancies in interpretation to maintain confirmability. These procedures add validity to the results of this case study.

Chapter 4

Results

Introduction

This chapter consists of five main sections. The first section offers rich descriptions of the teachers' instruction and interaction with students while implementing the lesson study, and a comparison of these activities to what goes on in their regular teaching. The second section provides specific details of (a) the teachers' collaboration during the planning and debriefing sessions, (b) the school context, and (c) lesson study unit/topic choice. The third section focuses on the interaction between the teachers and me as the lesson study facilitator, and also includes details about the school context. The fourth section discusses the benefits and challenges of implementing lesson study in high school math and science classrooms. Finally, the last section explores the possibility of the teachers continuing lesson study independently.

To preserve the privacy of the participants, pseudonyms are used. The mathematics teachers are indentified with the upper case letters "MT" and a number (e.g., MT1, MT2), while the science teachers are represented by "ST" and a number (e.g., ST1, ST2). The literacy coach, and coordinator, are each identified by their initial letter and the number "1," as there is only one of each of these involved in the study: L1, and C1, respectively.

Teachers' Activities

As mentioned earlier, three math teachers (MT1, MT2, and MT3), two science teachers (ST1 and ST2), one special education science teacher (ST3), and one literacy coach (L1) participated in this study.

Math group. Three math teachers participated in this study. Two of them were key players for implementing the lesson study, because they needed to submit an evaluation project to fulfill a school requirement, in which as yet untenured teachers must develop a project related to curriculum, in order for administrators to observe and evaluate their teaching. The other teacher was the chair of math department and had asked the other two teachers to participate in the lesson study as their project for "track II" obligation (for tenured teacher, they are evaluated in every two years for diming up with a project that would enhance their teaching in order to having productive teaching). Therefore, the regular math teaching of the two math teachers was observed, as well as their involvement in the lesson study, whereas only the lesson study activities of the chair teacher were observed.

Science group. There were three science teachers and one literacy coach who volunteered to participate in this study. They were all key players in the lesson study, but the literacy coach became involved after the science group changed their research goals. One of the science teachers was the chair of the science department, who encouraged the other participants to get involved. The literacy coach helped the science teacher develop the research lesson plan. Therefore, the regular science teaching of the three science teachers was observed, as well as their participation in the lesson study, while only the lesson study activities of the literacy coach were observed.

The following table shows a brief description of the six teachers.

Table 2

A Brief Description of the Participants

Participant	Education	Ethnicity	Gender	Teaching career	Teaching subjects for 2008 school year	Role in department	Experience of lesson study
MT1	AA Liberal Studies BA in Mathematics	White	Female	15 yrs	Algebra II Geometry Transition	Committee for new textbook	None
MT2	BA in Mathematics	White	Female	6 yrs	Algebra II Geometry Formal - Geometry	Quiet member	1 yr
MT3	BA in Mathematics MA in Mathematics	White	Female	23 yrs	Pre-Algebra Pre-Calculus Transition	Chair	2 yrs
ST1	BA in Business BS in biology science MAE in science education	White	Male	8 yrs	Basic Chemistry	Chair	2 yrs
ST2	BS Chemistry MS Analytical Chemistry BS Science Education	White	Female	18 yrs	Chemistry Honors-Chemistry AP Chemistry	Mentor	2 yrs
ST3	BS MS	White	Female	24 yrs	Self - contained Collaborative science	self-contained teacher	2 yrs

Teachers' regular teaching. The regular classes of the five teachers above were observed, with a focus on the connection between the teaching goal and actual teaching, the teaching style, and interaction with students. The regular classes of the literacy coach were not observed, since the literacy coach joined the project later.

Linear connection between the teaching goal and actual teaching. The pre-interview indicated that most of the participants had a teaching goal, and observations showed a linear connection between their teachings goals and their actual teaching. In the math group, MT1's overarching teaching goal was for her students to understand what they were doing. She especially wanted them to discover various strategies for solving problems with the new textbook for the 2008 school year. In order to encourage this, she let the students work as a group instead of individually. She emphasized collaboration through team work to solve math problems in class, trying not to provide one direct solution for each problem, but rather guiding them to the discovery of new or different strategies. However, she did offer lectures and direct answers to problems due to lack of time and varying levels of student understanding.

MT2's teaching goal was for students to have pride in their work, work hard, and be persistent in solving problems. Her specific goal for 2008 was to use graphing calculators more often. She set up groups and encouraged them to solve problems together. Since the new textbook required a lot of group work, she tried to follow the instructions in the textbook. Little use of the graphing calculators was observed; sometimes students used them for simple calculations, rather than complex algebraic operations.

Last, MT3's teaching goal was to get points across to students in a way that made sense to them. Specifically, her teaching goal for 2008 was to integrate groups more, and as a result she had been developing numerous group activities for her classes. Although she was willing to participate in this study, she did not want to be observed during her regular teaching, because she already had many outside observers of her classes, such as student teachers and other researchers. With respect to her complex situation, she was observed only during the lesson study

proceedings. As a result, this study did not examine whether the lesson study affected her instruction, unlike the other two math teachers.

For the science group, ST1's overall teaching goal was for students to appreciate science. He had previously taught biology and physical science, but was teaching chemistry for the 2008 school year, a decision that had been made by the department according to the needs of teachers and students. Since it was his first time teaching chemistry, his specific goal for the 2008 school year was to implement chemistry beneficially and see what he needed to change for the next year. He tried to help the students understand the concepts rather than forcing them to learn, since he identified his role in the classroom as facilitator. However, his instructional activities did not seem not to have any connection with his teaching goal, because his teaching goal centered on him instead of his students.

ST2 described her teaching goals as follows:

> I would say that one of my goals is to have the kids be able to…understand science at least at a basic level, and if they don't understand it, be able to know where they could get the information that they need. Just as being, um, an ap - a participating citizen in their—in our society, I guess. That they can handle the increase in technology in our society and—and understand its impact on them (ST2, Interview I).

She also explained her specific goals for the 2008 school year: to enhance students' understanding of molecules through visualization and the activities. In order to make a connection between these goals and her actual teaching, he imported a new piece of technology called WebMO into her classroom so that students could understand molecular geometry. In spite of this trial, the pursuit of ST2's teaching goal was limited by the chemistry curriculum.

Finally, ST3's main teaching goal was to assist students in preparing for the real world, and to provide them with strategies for learning. Her specific goal for the 2008 school year was to become familiar with the new textbooks and knowledgeable about other resources, including

technology. As a result, she tried to use technology, such as laptops and projectors, and developed a curriculum related to the real world. Nonetheless, her use of technology was very limited.

Various teaching approaches. In the math group, MT1 was very organized (e.g., preparing structured notebooks, worksheets, and stamp sheets allowing students to keep track of what they do). She also had some strict rules for classroom management. For instance, when she introduced exponential equations using graphing calculators, the class seemed a bit noisy. She said things like "focus" and "stop talking" twice, and then she issued a stronger warning when the class became noisy again. She also used technology often. The school had provided her with a laptop and a projector for her classroom, and she usually lectured with the projector and computer for efficiency and convenience. She used SmartView (a graphing calculator simulation tool) and a graphing calculator to show how to use a calculator properly.

MT2 regarded herself as a facilitator and an encourager in her classroom. She was especially careful to guide students in their use of the new CPM textbook, rather than laying out each step for them. Because they had a new textbook, the math department provided teachers with chances to gather and discuss the outline of their teaching according to the contents of the textbook. Interestingly, she identified herself as a quiet member of her department, often accepting the perspectives of other teachers, especially when they had strong opinions. Otherwise, she was trying to teach with her own methods, when she had enough confidence to do so.

MT3 was willing to accept the various perspectives of other teachers and tried to fulfill their needs as much as she could while cooperating with the administrators. During her tenure as department head, the math department had been through many curricular changes, adopting

textbooks such as *Discovering Algebra*, *CPM Geometry*, and *CPM Connect Algebra*. Therefore, the department provided more time for teachers to discuss the implementation of these new text books.

In the science group, the following vignette shows ST1's characteristic facilitation of his chemistry class. When he taught chemistry in the science laboratory, for instance, he prepared two centrally located mobile islands including all the materials that the students would need for the day's experiment. Once the bell had rung, he explained the procedures for the experiment, and then he demonstrated how to put the materials in the wells, emphasizing care with the hazardous materials. He repeated the procedure of the experiment one more time and told students to put on their safety goggles. After the signal to start, two boys came to the islands and began the procedure incorrectly. He observed their behavior and emphasized the first step again. He walked around and made sure that the groups were doing okay.

ST2 defined her role in her classroom as expert and guide, depending on the students' needs, because she noticed that different roles would enhance for students' learning of science: as an expert she told them what they should know, while as a guide she helped them discover facts.

ST3 collaborated with the other science teachers and taught science to special education students. Therefore, she had two different types of classes: a self-contained class in which she taught science to special education students, and a collaborative class in which she assisted teachers teaching regular science classes with a few special education students in them. After participating in the regular science class, she revised the curriculum based on her special education students' needs. She explained that she had three different roles, depending the circumstances.

> ST3: My goal is, probably, again, like a facilitator -uh, as far as, you know, presenting material. And also, in my self-contained, it's—it's not so much the material, it's exposure to the material. They probably will not remember a lot of it later on, or—so it's teaching life skills more respect for one another, and how to use a book as—as a resource how to use an index and those types of things.
>
> F3: And then collaborative?
>
> ST3: Um, it's some of those students, many of those students probably—not many, but some will be going into college, so it's probably the material becomes more important at that point. And also, make more connections. And also in my self-contained, making connections in science to real life—everyday life and how they can use it, or they can go, "Aha! Yes, that makes sense," those types of things. Real life—and again, the collaborative there are some students that will be going on to college so that's an important thing to remember (ST3, Interview I).

Static interaction with students. MT1 had strong opinions about what students were supposed to do in her classroom, so she seemed to answer students' questions directly rather than interact with them to reach an answer. Although she asked students many questions to encourage them to think about math concepts and made good eye contact while lecturing, she did not lead a discussion with students about math concepts.

MT2, on the other hand, was more flexible with students when she asked and answered questions. Students seemed comfortable when they talked with her. For example, while using a computer and projector to go over previous homework, she asked, "Which one we need to check?" One boy suggested a problem, and she solved it with the students. After arriving at the answer, students said, "OK," or "I got it." She asked and answered questions while walking around the classroom. Also, she made sure that all of the groups were doing what they were supposed to be doing.

Similar to MT2, ST1 was flexible and willingness to consider students' thoughts about scientific concepts when he asked and answered questions. However, his chemistry class was organized into pairs or groups, so he let students discuss among themselves rather than with him.

ST2 attempted to interact with students as much as possible, based on the observations of her chemistry class. She led the class by questioning students and setting up group work for them to understand the scientific concepts. Nonetheless, students were very passive in the classroom activities and slow to answer questions.

In the contrast, ST3 interacted with her special education students actively, but she was less active in her collaborative science class, in which she watched what the collaborative teacher taught and helped her prepare materials, such as strings and balloons, for science experiments. She played diverse roles across the two different science classes.

Delivery of the research lesson. The math teachers implemented their lesson study in the fall of 2008, completing everything by November, 2008. The first planning meeting was held on November 4th in order to set up the schedule. The second one was held on the 12th to write the research lesson plan, which was delivered twice by two different teachers, once on the 24th and the other on the 25th. The lessons were debriefed the same day they were delivered.

Unlike the math group, the science group implemented lesson study differently in terms of frequency of planning time, initial approach to lesson study, and involvement of the reading expert. The science teachers conducted lesson study in the spring of 2009. They planned it in January and then actually implemented the lesson in March and April. The first official planning meeting was held on January 9th to set up the schedule. During the meeting, the teachers noticed that the initial topic they had chosen for lesson study was not related to the goals of the science department. As a result, they decided to think about the relationship between their teaching goals and the topic of the research lesson for a while.

The brief second planning meeting was held on February 25th in order to set a tentative schedule. Finally, they gathered on March 25th to plan the research lesson, and this meeting

continued on March 31st. The research lesson was delivered twice by two different teachers: once was on April 6th and once on April 7th. The lessons were debriefed the same day they were delivered. The following table shows an overview of the lesson study implementation by the science group.

The math and science groups picked their research lessons based on the process of lesson study. The research lesson was taught twice, by two different teachers in each group. It focused on the connection between the department's goals and actual delivery, as well as interaction between teachers and students.

Connections between departmental goals and research lessons. In the math group, the teachers thought about their teaching goals and the theme of the research lesson, and I helped them make a connection between the two. However, they struggled because they did not have a clear notion of how to make that connection. MT1 wanted to choose the research lesson based on her teaching schedule:

> Three-two-one…I mean, probably what I'm going to do, because I'm going to have extra days, I'm going to have days where they do a bunch of homework in class. Which is really good for them anyways. Three-two-one is…how can I find…the equation…oh, and the cube root stuff. Um…what about this one? Three-one-five? (MT1, Planning I).

The other teachers wanted to choose the lesson based on their availability, without thinking about the purpose of the lesson. I suggested that they think about Lewis' (2002) guidelines: think about teaching goals first, discuss current students' stage, find a gap between them, and develop the theme for the lesson study. Following these steps, the teachers identified their goal of modeling real life situations with algebraic equations. They discussed how students understand linear and exponential equations and found a gap: they could not do quadratic equations or any other family or graph (other linear and exponential situations). Thus, they determined the research theme: for students to recognize and represent quadratic models.

Nonetheless, the teachers needed to rethink the lesson due to a lack of connection between their teaching goals and the research theme, although they had determined the research theme during the previous planning meeting. I provided more specific steps: look at the teaching goals, discuss current students, and determine the gap between them. I pointed out the math department goals, and the teachers began to discuss students and found a gap which would be a target for the research lesson. The following table shows how they decided the research theme.

Table 3

The Process of Determining the Research Theme From the Math Group

	Content
Goals of math department	Continue discussion on cooperative learning Implementing and support of CPM curriculum in Alg 2 Implementing TI-84 calculator skills in Alg 2
Teachers' discussion	MT2: *I still don't do a very good job with the cooperative learning, always. Getting the kids to buy into…the discovery part of it, and…and getting the roles set so that they're all active participants*. MT1: *I—I do do cooperative learning.* *My—my biggest problem, I think right now, I think, with them is, like, I feel like a lot of kids are lacking some fundamental skills that they need.* *Like, they understand they knew material. Like, they under—they understand the concepts that they're supposed to be learning, but they just don't have the skills* (MT1 and MT2, Planning II).
Students' situation	Not cooperative learning Comfortable for TI-84 - trouble for window Lacking fundamental skills
Research theme	For students to recognize and represent (algebraic models) quadratic models

In the science group, I reminded the teachers of the importance of making connections between the science department goals and the theme of the lesson study. ST2 presented the science department goals and led thinking a discussion of the gap between those goals and the students' current performance. ST1 brought up one issue related to their department goals: reading.

> I think being able to read and then apply what you've read, um, and…I know our students struggle, like on the ACT and stuff like that, um, but I know my own son just took the ACT, and he didn't do very well on it, and I know it's because he can't take the information that he read and apply it to the questions very well. He's not as good as his older brother was at that. So he—I need to help him, too. But our students have the same problem (ST1, Planning I).

Consequently, the science teachers needed more time to determine the topic of the research lesson with regard to their teaching goals. They decided to postpone the lesson study implementation until they had a clear idea of which topic would cross over into their different classes.

The literacy coach (L1) was invited to the third planning meeting via email, and ST2 brought passages she had found related to the topic of "gas law." As planned, she brought the standards of reading to review the relationship between the research theme and teaching goals. She specifically looked into the goals of the PSAE reading. Based on her findings, the team members discussed what kinds of reading skills were needed, and formed their goals: the improvement of inference, cause and effect, drawing conclusions, and identifying authors' purpose or interpretation. To teach these skills, L1 suggested starting with an easier text. She guided the other teachers in logically selecting passages for the topic and preparing questions for students.

In summary, as the teachers had had previous experience with lesson study, they showed a deeper understanding of what lesson study was. This fact allowed them to implement a lesson study that was more appropriate for their students' needs and their teaching goals. Under the pressure of tests and a new curriculum, teachers attempted to develop a research lesson to reduce those pressures and find the best way to teach in order to engage students in learning

Table 4

The Connection Between the Teaching Goals and the Focus of Research Lessons

Group	Teachers' teaching goals	Department goals	Research focus
Math group	MT1: Make her students understand what they are doing MT2: Impact on students for having pride, being hard workers, and being persistent MT3: Get the points across to students in order to make sense to them	Continue discussion on cooperative learning Continue communication between teachers of like courses Implementing and support of CPM curriculum in Algebra 2 Implementing TI-84 calculator skills in Algebra 2	For students to recognize and represent quadratic models Could they write the equations? Do they know about the names of shapes?
Science group	ST1: Students have an appreciation for science ST2: Enhance students to understand a molecule through visualization simulations and the activity ST3: Assist students be prepared for the real world, and to provide them with strategies in order to know how to learn. Become familiar to new textbooks and knowledgeable about resources including technology for 2008.	Improve methods of using formative and summative assessment in science classes. Work on purchasing i-clickers for department use, presenting to academic foundation on 9/23 and requesting them to purchase for science. Improve student science reading abilities. - Utilize the reading coordinator	In order to improve students' ability on the reading science passage for standardized tests, how are teachers able to encourage students to get involved in reading science topics with the various skills needed to do well on the standardized tests?

Dynamic interaction with students. In the math group, MT1 delivered the research lesson first. MT1 interacted with students when they worked as small groups. She walked around and helped solve difficult problems. The following conversation is an example of how she interacted with them.

S1: Ms. MT1?

MT1: Yes.

S1: Okay. I got zero equals *a*, sixteen minus three, and then I subtracted three—

MT1: Okay. Which means it should be a minus three.

S1: Okay.

MT1: And three divided by six—negative three divided by sixteen is negative three over sixteen. It's—right, but you need that to be a fraction. So it's negative three over sixteen.

S1: So *a* equals negative three over sixteen?

T: Mm-hm. So now, can you write the equation of your…

S1: Okay, yeah. But, like, see, this is right, but I don't even understand how he got that. Because—

T: How he got what?

S1: The little point thing.

T: Did you ask him?

S1: No.

T: Okay, ask him.

S1: How—we'll be here all day asking questions, though.

T: He's smart. He can tell you (S1 & MT1, Delivering I of the math group).

The next day, MT2 delivered the revised research lesson. She seemed to care about the scripts of the lesson plan more carefully than MT1. She communicated with students dynamically. The following conversation is an example of her interaction with students.

S2: What exactly are we doing? I have no clue.

MT2: Okay. What's—what's Part A say?

S2: Part A says to sketch the jackrabbit.

MT2: Yeah. Can you draw a sketch of this?

S2: Oh, I just draw it?

S3: On the graph paper?

MT2: Yeah. Well, your—your distances in the book should match the grid. So, like—

S2: Oh, like, like—

MT2: If this is three—

S2: --should be zero, zero right here?

MT2: You can put zero, zero there.

S2: Oh, okay, I get it (S2 & MT2, Delivering II of the math group).

In the science group, ST1 delivered the research lesson first. He modified the research lesson plan to fit into his Basic Chemistry class. He encouraged students to discuss as a small group to improve their inference skills. For instance, he introduced the topic of science reading to students and set up pairs for discussion. While the pair discussion was going on, he walked around and checked how students were doing. The following conversation is an example of how he interacted with one student (S3).

S3: I need your assistance.

ST1: Yes.

S3: For number four.

ST1: Okay. I think Casey's on the right track. I hear them say something.

S3: Yeah—I know what I want to say—

ST1: So what did you say?

S3: Like, they just did it. Without knowing what was going to happen. Like, they just heated it, hoping something would happen.

ST1: Well, it was kind of an accident, the way it was—it reads in there, it was kind of an accident, that it—the rocks that were around the fire got hot, right? And then, as they got hot, it mixed with the carbon in the fire, because the, like, wood burns, in terms of the carbon, and then the metal started coming out or the rock. So they found out how to get metal out of rock, but they didn't really know why the metal came out. Did they? They just knew that worked. But they didn't know the chemistry or anything. So that's kind of what…you can do something without really knowing. I mean…we all drive cars without knowing how the car works, necessarily. You know? But we're able to do it. So did you find that part? (S3 & ST1, Delivering I of the science group).

Since ST2 taught chemistry, she made several adjustments to the research lesson plan. She taped seven big pieces of paper to the walls and doors of her classroom for students to do group activities easily and to present the reasons for their answers. While students were in their reading pairs, she asked them what inference meant to them in order to introduce the idea.

> ST2: Can anybody in here tell me what we mean by inference?
>
> S4: Um, inference—[laughter] when you infer something, it means making an educated guess.
>
> ST2: Making an educated guess about something. So, um, that is part of the definition.
>
> S5: Making connections.
>
> ST2: Making connections. Very good.
>
> S6: Using your knowledge of other things to understand what the writer means.
>
> ST2: Okay, very good. So it's making an educated guess based on connections between different parts of a passage you might be reading, and bringing in outside experience. Okay, so we're going to continue that lesson today. This will be the last day that we do the lesson, uh, on inference. And I hope that, maybe over Spring Break, as you're—as you're reading whatever it is that you're reading…newspaper, newspaper, on the internet, maybe? Reading is a good thing to do. It's a good pastime. That you'll actually think about what you're reading, and you'll think about your process—your thought processes as you're processing what you're reading (S4, S5, S6 & ST2, Delivering II of the science group).

Overall, teachers interacted with students while they delivered the research lesson since lesson study focuses on student performance and teachers' anticipation of their performance. Also, lesson study encouraged teachers to have a researcher's mind toward their teaching as they planned the research lesson.

Teachers' Collaboration

While teachers planned and debriefed the research lesson, they discussed the topic they would use for lesson study and what should be taught in order to make the research lesson

effective based on their teaching experience. They also developed instructional strategies in order for students to understand the math or science concepts. As a result, teachers were able to share ideas about issues surrounding teaching and learning, and improving instruction.

Continuous discussion. The teachers engaged in a long discussion, not about the process of lesson study, but about implementing lesson study based on their positive experiences with it and making it work for their students. This discussion led them to share their points of view on student performance, the requirements of the math and science departments, student needs, and issues of teaching and learning. The teachers collaborated enthusiastically, producing much discussion in order to implement lesson study successfully.

Math group. MT1 participated in the planning meetings actively, but not effectively. She voiced her opinion on the lesson study topic and schedule based on her teaching schedule; she was not flexible. She was overwhelmed by the detailed steps of planning the research lesson at the first meeting. However, she engaged in developing the research lesson plan when I initiated it.

MT2, on the other hand, was willing to follow the research lesson planning protocol and schedule time for conducting the lesson study. She chose the topic considering student-centered activities and lesson study schedule. Significantly, MT3 guided their understanding of the purpose of lesson study, to set a research focus connected to their teaching goals, and to finalize the research lesson plans. Also, she assisted in making the observation questions.

The following table shows what the math teachers discussed during the two planning sessions.

Table 5

Overview of the Math Group Planning Sessions

Session	Purposes	Contents
Planning I	Scheduling for lesson study Choosing a topic for a research lesson	Discussing a topic which they would use for lesson study Discussing about what should be taught in order to make that lesson effective Choosing a template for the research lesson Setting the schedule for implementing lesson study Thinking about teaching goals and objectives of the lesson
Planning II	Confirming the research theme / observation focuses Completing to plan the research lesson Discussing preparation of materials for delivering	Finding the research theme related to department goals Thinking about observation questions and assigning who would take which question for observation Sharing issues of teaching current classes and strategies to solve those issues Writing a research lesson plan Determining a template for observation and guiding the observation protocols of lesson study

The math teachers discussed which chapter they would use for lesson study for. They started from which chapter they were looking for: either Chapter 3 or Chapter 4. They were teaching Chapter 3 at the time, so MT1 suggested it as the topic for the lesson study. However, MT2 hesitated, because she had only one lesson left from Chapter 3.

MT1 counted the teaching days in November, then asked MT2 about how far away they were, because of she was thinking about delivering the research lesson in different classrooms (MT1 was a bit ahead of MT2). MT1 was still looking for a lesson from Chapter 3 regardless of a connection with goals or the gap in student understanding. As a result, I emphasized that lesson study needed to be beneficial for students as well as themselves in order for them to choose a lesson based on those concerns. MT3 also added her opinion based on her previous experience with lesson study:

> Like, when we did ours, we did ours with the motion sensor, and our goal was to help students have a better grasp of rate of change. You know, they didn't seem to really understand rate of change. So we thought with the motion sensors we could help them (MT3, Planning I).

Then MT1 was frustrated about rethinking her teaching schedule.

> Help—mm. I don't know, I think I'm just a little frustrated, because I haven't—now that we've rearranged everything, I haven't…planned it all the way out to know…where I'm going to be…and how much I'm going to spread it out. Because I'm going to have to spread things out a little bit (MT1, Planning I).

MT2 picked a topic from Chapter 4 instead of Chapter 3 in order to have more time to plan the research lesson. MT1 agreed and considered the topics in Chapter 4. She was concerned about having a student-centered activity instead of a teacher-oriented lecture, and about using technology, which in this case would be the graphing calculator. MT3 asked, "And do they know how to do that before that? How to find maximum, minimum points on their calculator?" (MT3, Planning I) Finally, they chose the lesson for the research lesson.

Last, teachers chose from two templates for the research lesson plan: one created during the previous university partnership, and one developed by me. The former included a time line only, while the latter included more information: the name of the unit, date and time for delivering the lesson, participants, objectives of the lesson, research focus, observation focus, steps of the lesson, time for the lesson, teacher's activities, students' activities, and a space for writing observation notes. They chose the latter one developed by me.

The second planning meeting was for confirming the research theme and observation focus, completing the research lesson plan, and discussing the preparation of materials for delivering it. They discussed the observation focus in terms of Lewis' (2002) "examples of focal questions" (p. 35). The teachers mentioned an observation question:

> I did notice, by the way, now that I've been doing more problems in Chapter 3, that there's been quite a few homework questions where it says, "Graph $y = x^2$, graph $y = x^2 + 1$," you know, and they're supposed to sketch a—and—and then there's one that I just went over today, to go over it, but it was on there. $x^2 + 3$, and then parentheses $x + 3$ squared. And I told them, I said, "You guys need to make sure you're, you know, you're graphing these on your calculators, you're sketching them. Because this will be the focus of the next chapter. So they are having a little bit of…lead into it. Um, before we get to

> the chapter. As far as shifting, and—That would be—Because that's what the—that would be the academic learning (MT2, Planning II).

Discussion continued, and they finalized the observation question topics: academic learning (Could they write the equations? Did they know about the names of shapes?); motivation and engagement (How much time did students spend on the actual lesson?); and instructional features and information requested by instructor (What kinds of questions did students ask?). Finally, they assigned the observation questions to individual observers.

Science group. There were four planning meetings for the science group, due to the unexpected change of research topic. ST1 and ST2 participated in all planning meetings and shared their experiences, ideas, issues and concerns actively. Therefore, they delivered the research lessons. They were enthusiastic about developing the research lesson plan after they changed the research topic. Also, they invited L1 to help them improve the lesson plan with respect to current issues of the test and their teaching goals.

ST3 provided a different perspective on teaching because she came from special education. She tried to adapt the research lesson plan with her students after implementing the lesson study. L1 supported the other teachers beginning with the third planning meeting, when she was invited to join. She provided numerous resources and spent extra time meeting with the teachers to choose the research topic and materials (e.g. passages, questions, handouts). Thanks to the efforts of all the members, the science group finalized their research lesson plan with my help, as the math group had. However, they went through the planning protocol more independently than math group had. In addition, they developed observation questions individually, according to their diverse interests. The following table shows what the science teachers discussed during their four planning sessions.

Table 6

Overview of the Science Group Planning Sessions

Session	Purposes	Contents
Planning I	Presenting the initial plan to team members lesson study Confirming a topic for a research lesson	Explaining a topic chosen previously by ST2 Discussing the connection between the science department goals and the research theme of lesson study Deciding to spend more time to think about the connection for implementing lesson study
Planning II	Deciding a tentative schedule for lesson study Checking a possible topic for lesson study	Discussing about the reading topic Referring a reading specialist Setting the tentative schedule for the next meeting
Planning III	Scheduling for lesson study Choosing the topic for the research lesson	Reviewing the standards and goals Confirming the connection of the research theme to the teaching goals Discussing a mini unit for lesson study Setting the schedule for implementing lesson study
Planning IV	Confirming the research theme Completing to plan the research lesson Making observation questions	Writing a research lesson plan Sharing issues of teaching current classes and strategies to solve those issues Discussing about observation questions

At an unofficial meeting with the science teachers in Fall 2008, ST2 suggested using her lesson plan as the research lesson plan, since she had developed it through the university WebMO workshop, and it allowed students to draw chemical bonds, to visualize the molecular level. ST1 and ST3 agreed to this, so they determined that their research topic would be "Discovering Molecular Geometry."

At the first official science group planning meeting, ST2 explained how to use WebMo using the projector. During her explanation, she tried to adapt her lesson to ST1's class, because he taught Basic Chemistry, while ST2 taught Chemistry. ST1 had no experience with WebMO, and he did not seem to be able to find a good unit in which to implement the lesson. Consequently, the science teachers decided that they needed more time to choose a new topic.

They decided to postpone implementing the lesson study until they had a clear idea of which topic would better fit all of their classes.

During the third planning meeting, the science teachers discussed the outline of a whole group reading activity that was four days long. Considering a unit instead of just one lesson seemed to be helpful, and eventually they developed a science reading unit. They had not decided when to deliver and debrief the research lesson yet, but they agreed that they would meet one more time to clarify all the details for the lesson study planning. ST2 sent an email about the content of the mini-unit before the final planning meeting based on the discussion at the previous meeting.

At the final planning meeting, the teachers determined the actual schedule for the lesson study. ST2 preferred that ST1 deliver the research lesson first, so he did. I pointed out that they needed to come up with some observation questions and presented some examples created by the math lesson study group. This helped the science teachers discuss the observation questions:

> ST1: I—I don't know that we're necessarily focused on academic learning at this point. I think we're more looking for a…a skill—skill of being able to take the information and apply it. Without pulling it right off the page. And then I think motivation is—is probably social behavior, that's definitely going to be something—
>
> L1: Right. I think that's something that you could—
>
> ST2: So, and there's lots of things that, if you haven't had them do it, like, you know, how long's it going to take them to get through that group? Those are all kinds of things that they don't —they don't necessarily automatically know how to do that (L1, ST1 & ST2, Planning IV).

To make clear their ideas, I let them write observation questions according to the categories: group dynamics, effectiveness of lesson design, and utilize inference skills by each teacher. The following table shows them.

Table 7

Observation Questions for the Research Lesson of Science Group

Participants	Observation questions
ST1 & ST2	What are the group dynamics? 1. Do the students show evidence of good communication skills? - Do students make eye contact when speaking and listening? - Do students acknowledge each other to speak? - Is there evidence of active listening such as head nodding and verbal cues? - Do the students verify understanding by paraphrasing? 2. Are all students participating? - Do the students encourage participation of all members? - Are there students who appear to do little or nothing? - Do the students take turns? - Does one person in the group take over? 3. Could the students arrive at a consensus? - Was there evidence of compromise? - Do the students complement each other for good ideas?
ST3	Effectiveness of lesson design 1. How much time did the introduction and instruction take? 2. How long did it take for the students to get into their first groups? 3. How long did it take for the students to get into their second groups? 4. Was the method used to break the students into groups efficient? 5. Were the sizes of the groups effective? 6. Were the instructions from the teacher clear? 7. Did students ask many questions after instructions were given? 8. Did students ask many questions of the instructor during their group work? 9. Did students appear comfortable in their groups? 10. Did all students participate in the larger groups? 11. Which students appeared to be leaders? 12. Were all students engaged in the lesson? 13. What were student comments at the end of the lesson? 14. Did the students appear to enjoy this type of lesson? 15. How effective did the teacher think the lesson was?
L1	Utilize inference skills 1. Students to answer the inferential question asked and also being able to explain what evidence they used in the text to create their answer. 2. Students should be able to refer to a piece of information in the passage to create their inference.

Developing instruction. The teachers discussed how they would develop or improve their instructional strategies based on anticipation and observation of student performance during the planning and debriefing sessions. They attempted to formulate an effective lesson plan and expanded their points of view on student understanding based on their observations of the research lesson delivery in order to revise the original research lesson plan. This process enabled

the teachers to think about the students' understanding of math or science concepts related to improving their instruction.

Math group. The math teachers discussed instructional strategies when they decided on the research lesson. I emphasized that instruction would stem from their current teaching practices, rather than creating a new strategy to make students understand better. Teachers tried to share their strategies, concerns, issues, and challenges surround the development of a research lesson plan. The following example shows MT1's contribution.

> I mean, it's always, they work, you talk, they work, and…like, yesterday, what you saw, was totally teacher-directed. You know, they were discovering. But I would prefer—I prefer it when they're in their groups and I just, kind of, summarize, or have them summarize. … And then the last two are just them practicing it. [pause] So I—I wouldn't—I mean, it's not a lot of questions. I don't think it would be…because four-forty-six and four-forty-seven are really the same question. That's really the focus—I mean, that could take up over half the period. Because forty-eight and forty-nine are just, um…you could let them work for twenty minutes or something, in groups, on this, and then…you know, go over it on the board, what everybody's been coming up with. And hopefully get all three of these, um, grids, and show it all three ways. Like, that's probably what I would try to get the kids to do. Is work on it, and then draw—draw it on the board and say, "Where could you have put your axes?" And put all three, and then, "If you put your axes here, how did you do it? If you put your axes here, how'd you do it? If you put your axes here, how'd you do it?" And get the three different equations. And then…and then hopefully there would be ten minutes or so left for them to do the last two. And then—that doesn't, you know, work out that way…that's something we could discover when we do it (MT1, Planning I).

Moreover, teachers shared current teaching issues and strategies to resolve them. MT2 mentioned the issue of motivation, and MT1 agreed. They tried to find a connection between the issues that they had discussed and their observation focuses. As a result, they discussed more behavioral issues in order to consider how they could address those issues through the research lesson.

During the debriefing session, members suggested some ways to modify the lesson for better delivery during the second attempt. First, MT2 suggested including more algebraic skills.

As a result, the discussion of 4-47 needed to be expanded from *a* to *e* instead of from *a* to *c*. The emphasis on activity *e* would lead students to think of different equations. In addition, MT1 thought about her next lesson based on her experience of delivering the research lesson.

MT1 also pointed out an interesting issue based on her observation of MT2's delivery of the research lesson. Students needed algebraic skills which they were supposed to have learned in Algebra I:

> Well, it's the idea of doing the opposite, which is ironic, because in the Algebra I book, um, if you remember—I don't know, they were talking about it, and I can picture the problems—they get these bizarre-looking equations that they're supposed to undo. So supposedly, they're supposed to have that concept. Of undoing. And doing the opposite, no matter what the equation looks like. So theoretically, these kids should be better at that than our former kids. And—and I think we just may be in that initial slump, and I think we may see it go back up next year (MT1, Debriefing II).

As the modification of the research lesson plan, MT2 guided students to think various ways of obtaining equations for 4-47. Also, she pointed out how to use the graphing calculator properly. She asked several questions to lead students' thinking (e.g. where is your vertex on the graph? which point do you want to plug in? which one am I putting in for *y*? How are we used to seeing this written? if that was the case, okay, how far did he jump? Does my *a* change? Did it get any wider? Did it get any more narrow?) As a result, the teachers accepted that they needed to change their teaching for the next semester. Their active discussion changed their points of view on students' needs.

Science group. Day 3 of ST2's mini-unit idea served as the research lesson plan. To develop it in detail, the teachers started from how to pair students up. The teachers shared different ways of accomplishing this:

> And it doesn't matter, you just have two sets of ways to pair. You can do—you can hand out…you can go by color and numbers. Or, like, what you can do is have on one sheet, you can have a sticker, because they're going to need two sheets. They're going to need the reading sheet, and they're going to need the writing sheet, right? So on one—on one

> sheet, you have a, like a pink sticker with a number one in the middle. On the other sheet that partners up initially with that will be a pink sticker that might have a six in the middle. And then—then you—you tell them, "Okay, find your pink partner," and then when they get through all of it, you say, "Okay, find your—your group that has—that are all sixes. Or your number group." You can do it like that. And you just—all you did was have them pick up a piece of paper, and it's all set (ST2, Planning IV).

They moved on to making the questions follow the format of the actual test they were simulating (e.g. 750 words and 10 questions). ST1 suggested that they use open- ended questions instead of multiple choice questions, and the other teachers agreed. Then, they set up the scenarios of the research lesson plan: 5 minutes for pairing up, 8 minutes for reading passages, 10 minutes for discussion, 10 to 15 minutes for the carousel, and 10 minutes for discussion and comparison as a large group. While outlining the research lesson plan, the teachers shared their instructional knowledge of two different subjects: Basic Chemistry and Chemistry. ST2 mentioned an issue of having a large group activity, and they discussed it:

> ST2: The one problem that I'm thinking about is that they don't all have their own sheet.
>
> ST1: But they should have been involved in the—
>
> L1: To record their responses?
>
> ST1: But they should have been involved in the discussion, right?
>
> ST2: So maybe they take their own notes—and then you have one sheet for the group of four.
>
> ST3: So the written material's on one sh—only one person has that?
>
> ST2: Well, for the reading, for sure, only one has it.
>
> L1: Right.
>
> ST3: I think that's difficult. For a lot of people, if you need to see it visually, and some people—when you're taking the test, it's in front of you, rather than auditory, right?
>
> ST2: Well, we could do both. That's all right. But I'm just saying, I—and, you know, sometimes, having a, you know, making them cooperate that way is not—it conflicts with the goal of the lesson. So you have to use your best judgment.

L1: I mean, one thing is, you can do is have the extra copies for when they carousel, sitting there, and "If you don't have the passage, here's the passage." So before they carousel, you know, you can give them all their own passage to go on to the carousel with. So when they're reading it, they only have one in their group, but now that we're done with our group work, and the questions—

ST1: Well, when they're reading, there's only going to be two of them. So then when they go to their next larger group—

L1: Then you can get the other—

ST1: That's not a bad idea.

L1: You can get the other person their passage to take with them. So everybody has a passage.

ST1: To refer back to if they want to (ST1, ST2, ST3, & L1, Planning IV).

During this discussion, L1 provided professional knowledge related to reading For example, she explained the instructional skills for inference. Even after profound discussion among the teachers and explanation by L1, they were not able to set the inference questions related to the reading passages for the research lesson. Therefore, ST2 set one more meeting with L1 to accomplish this, after which she would share the questions they created.

During the debriefing sessions, ST3 brought up the students' lack of algebraic skills, based on her observations. ST1 agreed that his students had weak algebra skills and explained that he had already talked about this issue with the superintendent. He mentioned that the math and science departments needed to meet to discuss it sooner, but he did not seem to be optimistic about that actually happening. Based on the discussion, the research lesson plan was revised. Since ST2 taught a different class, she made some changes for her class, such as not providing the questions right away, as ST1 had. For example, She posted seven big piece of paper to the walls and doors of her classroom for students to do group activity easily and to present their reasoning of answering questions. She also put all materials (e.g. handout of passages,

worksheets, color stickers, index cards, markers etc) on her table for them to grab according to her guides. She presented her lecture through the power point file using a projector in order to inform clear instruction for students.

After the second delivery, ST2 reflected that ST1's class was better to look through all content of the research lesson plan due to the lack of time. I asked her how she could avoid going over the time limit, and she thought that extending the lesson over two days would be better:

> Well, as I was watching them, I was kind of trying to adjust. Like, I handed out their B sheets instead of having them come up and get them—And I, um, didn't even hand out the notecards. I'm not sure—because I was trying to keep it moving along. We were under three minutes on the carousel part. I just waited until everybody got done. I—I'm almost thinking it would be better to extend it into a two-day lesson, maybe (ST2, Debriefing II).

Overall, the science group was able to share vivid observations. The teachers focused and listed to each other. These attitudes resulted in improvement of the research lesson plan. Since they had diverse observation questions, it was very interesting to listen to their various perspectives on students' performances during the debriefing.

Teachers' Interaction With me as a Facilitator

During this lesson study, the interaction between the teachers and me as the facilitator was a focus because it was a key element in implementing lesson study without funding. Support from the school was also very important.

Support from the school. To implement lesson study in this high school without funding, the school provided support in the form of two people: a curriculum coordinator and a literacy coach. These participants played an important role in the lesson study process.

The curriculum coordinator. The curriculum coordinator had previously participated in the funded university partnership and had provided tremendous support for the facilitators and

teachers of that partnership. She had organized schedules for summer workshops, follow-up workshops, meetings between facilitators and teachers, and substitute teachers as needed. She had also observed how lesson study was implemented during the university partnership. She had come away from this experience with a positive opinion of lesson study's focus on student-centered learning. However, she pointed out some challenges she had discovered during her observation of lesson study:

> Um, I think the challenges for the most part have been time. Um, ability to find time to work together. Ability to work through those lessons and drill down to very specific skills that you want to look at. And—and teachers feeling that they have to cover curriculum, rather than working on concepts, um…to the point where they can really figure out what they need to do for students. And then, applying that—what they've learned from that—further out. I think there's a disjoint, um, that's disjointed right now (C1, Interview).

The curriculum coordinator encouraged teachers to participate in this study to fulfill the school's Track 2 evaluation requirement. She arranged substitute teachers for the teachers who participated in the lesson study so they did not have to worry about missing their own classes when they observed the other teachers. She also helped me send informed consent letters to the parents of students who participated in this study indirectly.

The literacy coach. Since the science group chose a topic related to testing and reading comprehension, the literacy coach was asked to join their lesson study group. She collaborated with other teachers when they needed her help developing test questions, analyzing national test questionnaires, and helping students understand the test. She had previously taught English to grades nine through twelve for five years at a different high school, after which she had gone back to school to become a reading specialist. After receiving her reading certificate, she had taught English part time, as well as being the literacy coach at the high school in this study. At the time of this study, she was working full time as the literacy coach.

Support from the facilitator. Based on their previous experience with lesson study, the participants requested several things from me as the facilitator. Since the former facilitators had written the lesson plans for the teachers, MT2 stated that she needed things like templates for research lesson plans and observation, ideas for how to word their notes, and clear guidance during the process of the lesson study. MT3 indicated that she needed a sufficient explanation of the process of lesson study and some suggestions for what to do next. ST1 also wanted a well-structured guide of all the steps of lesson study and confirmation whether the teachers were on the right track. ST2 needed specific directions for lesson study, and ST3 needed more details about what she was supposed to do and help planning the research lesson plan.

Accordingly, I attempted to provide practical and efficient assistance, such as preparing research lesson templates and observation templates, providing specific information about what lesson study is and what its procedures are, distributing informed consent letters for students and parents, coordinating schedules, cooperating with the coordinator to remove any obstacles to the lesson study process, and communicating with the individual participants about how they were following the procedures of the lesson study.

Preparing lesson study materials. The math teachers expected a lot of assistance from me, because only one of them had had experience with lesson study, and they were using the lesson study as their evaluation project. They needed help planning and writing the lesson plan and the observation template.

> Um, the last time we did lesson study, we— Facilitator helped us plan and kind of get the writing - And after then, he didn't do much. So I'm not sure…I think a little more help with the revision along the way—may be nice. And just some of the forms and the filling out, and the wording, and some of that (MT2, Interview I).

As a result, I prepared the initial lesson plan based on their first planning meeting and revised it with them at the second planning meeting. I also prepared the observation template.

The research lesson plan was revised during the first debriefing meeting based on their observation of the first lesson delivery. I modified it, including all changes that they wanted. In addition, I revised the second observation template to accommodate the changes to the research lesson plan.

Importantly, I initialized the evaluation project summary for them following the format of the lesson study report referred to by Lewis (2002) and Wiburg and Brown (2006). The summary included the overview of the College Preparatory Mathematics (CPM) curriculum, learning standards, the overview of Algebra II Connection, the goals of Algebra II Connection, the outline of the textbook, a summary of the research lesson (unit, unit objectives, overarching goals of teaching, actual situations of students, learning objectives of each lesson in the unit, focus of research lesson, observation questions, research lesson plan), and teachers' reflections.

Since the science group had had more experience with lesson study than the math group, I researched what they expected of me. Did they want me to observe or facilitate? They asked me to be a facilitator, because they needed to me to keep them on track while they were implementing the lesson study.

> I think…I think we can always use the input—of a facilitator. Um…we've all been through it, right—the other—ST2 and—I know she has. So, I mean, we've done it, so, I mean, maybe we could kind of work through it, but I would be fine with you facilitating. Just to make sure that we hit—all the areas that we need to hit. Because we—we get sidetracked sometimes (ST1, Interview I).

> I would say a facilitator. Simply because I don't think any of us have had that much practice at lesson study that we don't need facilitating. That, you know, because I'm assuming an observer wouldn't jump in and say, "Well, you know, it's better to do it this way." I think we need a facilitator (ST2, Interview II).

As with the math group, I helped the science group develop the research lesson plan. I created the initial lesson plan based on the discussion in the planning meetings, and revised it with the teachers who would deliver it. Also, I prepared six different observation templates,

because each teacher had different observation questions according to their interests, instead of having the same questions with different foci, as the math group had.

Guiding the lesson study protocol. The participants requested a sufficient explanation of the lesson study process, specific directions for the steps of lesson study, details of their roles, help planning the research lesson plan, and help staying on track

> Well, they're going to need…they're going to probably need you to explain the process o them. Because MT2 went through it only one time—and MT1 never done it. Um, so they're going to need you to probably explain the process. They'll probably rely on your leadership as far as setting the dates and knowing what to do next. Especially with the planning part of it. So they're going to probably need some leadership. Knowing what to do (MT3, Interview I).

Accordingly, I provided practical resources about the lesson study process for the planning meetings (e.g. guidance for connecting the research focus to the teaching goals, examples of observation questions, steps of debriefing and reflection). Participants also needed detailed guidance about the lesson study process and clear directions (e.g. observation focus, lesson study templates) from me as the facilitator. Following their needs, I provided helpful resources for them to understand the process of lesson study clearly. I prepared materials based on Lewis's (2002) detailed lesson study steps. Since the math group had implemented their lesson study before the science group, I referred to the products of math group, such as their research focus, observation questions, and research lesson plans. These actual examples enabled science group to follow the steps of lesson study.

The bridge role. The participants asked me to set the schedule for the lesson study, communicate with the coordinator in order to obtain school support, and correspond with the individual participants about how they were doing. In fulfilling their requests, I served as a bridge between the participants and the implementation of the lesson study.

Coordinating schedules. When the math teachers set up their times and dates for implementing their lesson study, I prepared a tentative timeline for them. Upon viewing the tentative schedule, MT1 was reluctant to use her lunch hour, which was from 12:00 – 1:00 p.m., for the lesson study: "I don't think we necessarily have to work it around our lunch," and "I honestly don't want to be doing all my planning on my lunch" (MT1. Planning I). She emphasized that they could get substitute teachers if they needed them for the lesson study. However, MT3 explained a problem with getting substitute teachers:

> The subs do complicate matters, because then we have to look at the staff development and the board room calendars, and make sure there's not a lot of subs the day that you need them (MT3, Planning I).

For the science group, three members of the team (ST1, ST2, and me) met to set a tentative schedule during the regular science department meeting. Hence, the planning meeting was very brief. I prepared the tentative schedule for the science teachers, and they discussed it, deciding to choose the topic and an article, and develop an initial lesson plan by March 25th. In addition, they planned to finalize the lesson with all members, including the reading expert, and to set up the dates for the first and the second lesson delivery on the same day. I needed to help them develop observation sheets and examine the informed consent letter for the students and parents. They tentatively scheduled the research lesson delivery for April, before Spring Break. Furthermore, ST2 mentioned the need for the reading specialist to choose the reading topic, based on their goal of integrating reading into science. She would contact the specialist and ask her whether she would be able to participate in the lesson study.

> ST2: So we have them read a passage…and answer questions? And incorporate questions that are—that have some of the words in them that they need to understand, like infer? That kind of thing?

> ST1: Yeah. And maybe have some, um, higher level thinking questions. You know, not just finding facts in the passage. Right. Unless you wanted to just do—do an actual passage from a sample test or something like that. I don't know if…
>
> ST2: I think that's kind of…the reading coordinator's area. A lot of times, those are just kind of disjointed to me (ST1 & ST2, Planning II).

The teachers determined the actual schedule of lesson study at the final planning meeting.

Cooperating with the coordinator. When the problem with using substitute teachers emerged during the math group discussion, I requested a meeting with the coordinator to resolve this matter. We discussed how to help the teachers without creating problems for either the participants or the school. Fortunately, she was able to find funding to obtain substitute teachers for the participants when they needed to observe the other teachers and debrief. As a result, all of the participants were able to conduct their lesson studies without worrying about leaving their classrooms.

The coordinator also helped me send the informed consent letters to the parents of students who were involved in this study indirectly. First, I confirmed the content of the letter regarding the context of the school with her. She provided a rich description of the school context, based on which I revised the letter. Later, she provided mailing addresses. Thanks to her help, I was able to help the participants implement lesson study without any legal conflicts.

Checking individual participants. The participants had asked me to keep track of their progress on the lesson study project when I had interviewed with them previously. Therefore, I asked them about their concerns whenever I met with them and attempted to resolve any issues. For instance, ST2 and I met to go over the activities that they planned to do before the third planning meeting on March 18th. ST2 had chosen "gas law" as the topic, and she had passages for it but was unsure about the ACT format, which she wanted to simulate. She mentioned that she needed help from L1. She also said that she was not sure about the goals of this lesson study.

She pointed out that all of the team members needed to discuss it as a whole group. Even though they had discussed the goal of lesson study in previous meetings, it still seemed unclear to them. Therefore, I suggested that she read the ACT test booklet for examples of questions.

The meetings with the individual teachers facilitated the implementation of the lesson study by enabling the teachers to feel confident in their understanding of the process of lesson study, and to communicate with other team members to share ideas and experiences.

Benefits and Challenges of Implementing Lesson Study

Having had previous experience with lesson study, the teachers had an idea of the benefits and challenges of implementing a lesson study. Therefore, they were able to implement a lesson study that was appropriate for their students' needs. The teachers attempted to develop a research lesson to reduce the pressure of tests and the new curriculum in order to engage students in learning.

Previous thoughts and expected benefits and challenges. As described earlier, MT1 had had no prior experience with lesson study, but MT2 and MT3 had both had some experience. MT3, who had implemented two lesson studies previously, thought that lesson study helped teachers examine their lessons carefully, prepare materials efficiently, and collaborate with other teachers. She expected to obtain the same benefits she had before: to see what students were actually saying during the research lesson based and to see whether they were making a connection between discovering and understanding mathematic concepts. She mentioned that planning would be a challenge for her group because it would be the first time for them to implement lesson study together.

> Um, I think the—the challenges, and the planning stages, um, trying to prepare the lesson—the script, and all of that. I think that's kind of cumbersome at first. Um, but, the

> experience itself, once you're actually delivering the lesson, is, I thought, very beneficial (MT3, Interview I).

MT2, who had implemented one lesson study previously, was confused about lesson study, thinking that it was the process of developing a lesson plan:

> Um…I'm—sometimes get confused on the goal of it being for the lesson—or, like, a global goal. Um, ar-ar—and, I guess, how to articulate how to take it from this one lesson into something that we can use—Because isn't that that goal, is to have kind of a template that…we can…something that will work in more situations? Um, and I think it's good to observe each other, and to plan together (MT2, Interview I).

She listed what she saw as the benefits and challenges of lesson study. According to her, having more ideas when planning the lesson plan was beneficial, and time limits and different characteristics of team members were challenges.

Interestingly, MT1 had a general idea of lesson study even though she had no experience with it, having heard about it during a project sponsored by the university partnership: "I know the plan is to do a lesson, and then revise the lesson, and then do it again" (quoted from the interview with her). She thought that the lesson study would be beneficial for improving their lessons and having them flow naturally. She expected to observe other teacher's classes, and she anticipated time being a challenge.

The science group had three teachers who had had positive experiences with lesson study. ST1 had experienced lesson study previous two years with the university partnership and thought that lesson study had potential and was an ongoing process. He said that in order for the lesson study to be effective, the teachers would need to understand its benefits and be committed to the process. He listed benefits such as peers being able to see things that the teacher delivering the lesson may have missed. Also, he pointed out that time would be a challenge, because teachers do not like to miss their classes. Even with support from administrators, it would be difficult to find time to work together during the school day, since teaching is teachers' first priority. Also,

he said that the science teachers tended to be skeptical about lesson study because its success had only been proven in other countries. He wanted "to try to be objective in the process and try to help enhance the results of the lesson and the delivery" (quoted from the interview with him). He mentioned that the teachers' different backgrounds and perspectives might be a challenge.

ST2 had observed research lesson delivery as a participant in lesson study. She thought that this experience had not influenced her directly; however she regarded it as a very in-depth effort to improve lessons. She saw the benefit of having different perspectives in order to improve what went on. She also thought that to delivering the research lesson again after debriefing was beneficial. Still, she thought that a lack of understanding of the level of detail for the procedure of lesson study was a challenge.

ST3 observed had also observed research lesson delivery, and she emphasized lesson plan development and instructional improvement. She had had experience with lesson study for two years with the university partnership, having collaborated with science groups as a special education teacher instead of as an active participant in the lesson studies. She had a positive impression of lesson study:

> Um, it's interesting. And I think it's, um, um…very…eye-opening, and it's an awesome experience. I think it takes a lot of time and, but you—it's valuable, as far as focusing on one lesson. Of course, when you're focusing on one lesson, then you can apply a lot of the strategies and techniques to other lessons as well. So it's a very interesting concept I think (ST3, Interview I).

She expected to learn from other teachers and to have time for collaboration. She thought that knowing exact her role in the lesson study would be a challenge.

Benefits of implementing lesson study.

Both the math and the science group implemented lesson study successfully in terms of effectiveness of the research lesson in order for students to understand the intended concepts

through active participation in the lesson. To support this claim, teachers gave very positive feedback on the benefits of implementing the lesson study.

Table 8

The Benefits of Implementing Lesson Study

Participant	Benefits
MT1	It is helpful to be able to break down the process for the lesson. It would be great to have the time to do this for almost all lessons. It was a great opportunity to observe someone else's Algebra II class.
MT2	Lesson study is useful because it allows teachers to collaborate. Another major benefit of lesson study is the collaboration that takes place after the lesson is presented to discuss issue that happened that may not have been thought about in planning the lesson.
ST1	I learned new techniques for finding reading passage and writing sessions for students to practice inference.
ST2	The extent of work involved in creating through lesson study. Suggestions and techniques for improving lesson study.
ST3	The lesson study process can be a valuable tool for teachers in all areas of the curriculum.
L1	Good reflective practices. A good framework for setting up observation forms.

The math teachers showed a deeper understanding of lesson study compared to their previous experiences with lesson study with the university partnership.

> Um, it—it was good. I think the best thing about it is just seeing other teachers teach. Not necessarily the lesson study itself, but that's part of it. And that's probably the most useful part, is going into someone else's room and seeing the way of an observer instead of being the instructor (MT1, Interview II).

> I think it's very helpful, just collaboration with other teachers. Ah, it seems like it's hard to find time to actually talk about lessons. Um, to get people's different perspectives. Um, it's very helpful to kind of have time to reflect together (MT2, Interview II).

MT3 stated what she had learned through implementing this lesson study:

> I don't know if it's a learning point, but I've been struck by, um, how much more challenging we've made the curriculum for our lower level students. Um, you know, watching the different lessons in action, um, I'm impressed at how deep we're making them think about mathematics. And the level of mathematics we're pushing these kids into now. I think we've made a jump. A good jump (MT3, Interview II).

Importantly, they talked about the possibility of continuing lesson study. MT1 stated that she would do lesson study if she had time:

> Not if we don't have the time. It would have to be time during the school day, because I don't have time outside of my workday to do it. Then we would do it. Yeah (MT1, Interview II).

MT2 mentioned that well written materials were important for continuing lesson study:

> Yes. I think we can—Um..I would say we still need the forms and things, that—to fill out. Um, but we could definitely do, like, more an informal…type thing, where it's more for us, where we understand everything we write, and we don't have to have it quite as nicely written out. If that makes sense (MT2, Interview II).

However, MT3 was more dubious about continuing lesson study:

> Might be a little—some people would do it, I don't know. I don't know if they're getting tired of it, or if they—I don't know (MT3, Interview II).

The science group provided insights into this lesson study as well. ST1 mentioned its usefulness:

> I think it's very useful. I think it can be very helpful. I think that the—you know, there's a—some resistance at times, um, from…teachers and from administrators as far as the time component that's required. But I think the benefits of that time are, uh…pretty big. I think that that can help a lot. So, I think it's something that…it—you know, if it's possible to use more (ST1, Interview II).

ST2 emphasized the effectiveness of lesson study:

> I liked how our lesson study turned out. And I think I will—I will incorporate—my goal is to at least do one or two more next year, and just keep adding to that. And see, um—because I really feel like they need those skills that are not being taught directly to them for the PSAE. And it wouldn't necessarily have to be a science reading skill. It could be a graph analysis skill, but just addressing it in some way. And I liked—I liked the group aspect of it. So I was happy with how it turned out (ST2, Interview II).

ST3 mentioned the benefit of collaboration:

> Oh, I think it's a really good thing. And as I look back on it, when I first started teaching here, they had a program for new teachers. All new teachers went through it, and it was called…I can't think of it right now. But we were put in groups, and we went and observed other teachers teaching. It was similar to the lesson study, but it was cross-categories, like you would go into and watch a math teacher, or a math teacher would

> come in and watch your special education class. And then you would get together and make observations, and it was never critical or threatening at all. It was just seeing what the observed teacher did that. So that concept, again, we had done, you know, twenty years ago, twenty-five years ago, but then they died—that faded out. I think the lesson study is very beneficial to both the teachers being observed and those working together and observing, and then coming together and analyzing—yeah, it's very beneficial (ST3, Interview II).

Finally, L1 indicated a positive impression of lesson study:

> I'm highly impressed. It gave me a lot of insight where to go with having conversations with teachers. Um, also encouraging that objective practice and reflection by teachers. Um, a lot of times there's always the, um…[interruption] There's always the, um…feeling that I might be evaluating them when it comes to their position at the school, but I'm not. I'm only there to help them. I'm not there to evaluate. Um, so I think the lesson design—the lesson study design and framework for how we did our observations was really clear-cut and very objective, that teachers wouldn't see it as a personal attack on them. And sometimes that's what happens in my position, is they think I'm there to tell them they're a bad teacher. They don't realize I'm there to highlight, um, the good things that you're doing and focus on those. You know, and tweak some other things that might not be going right, or if it's student issues, things like that. So, I mean that, hands down, was something I took away that day (L1, Interview II).

In addition, after implementing lesson study, the math teachers mentioned that they had benefited from my help: MT1 emphasized my explanation of the process of lesson study, MT2 said that my writing and keeping them on the track was helpful, and MT3 mentioned that I had provided materials and helped them focus on the connecting their lesson to the goals. With my help, the science group was able to conduct the lesson study without any serious conflicts. The teachers listed ways in which I had helped them: scheduling and organizing, providing clear information about lesson study protocol, being friendly and flexible, and providing practical materials (e.g. observation format, lesson plan templates).

Challenges of implementing the lesson study. Even though the participants had benefited from the lesson study overall, they did face some challenges implementing the lesson study. MT1 had some problems with the pace of lesson, and MT2 emphasized the lack of independence to implement lesson study on her own and inform her other colleagues about it.

ST1 said that meeting with other members was time consuming, and ST2 added that there was the problem of having enough space, too, which was not under the teachers' control. ST3 was not sure she understood what lesson study was for, and L1 brought up the issue of following the lesson study process, especially being an observer and having other teachers as observers. The following table shows what they thought about the challenges and concerns of implementing lesson study in detail.

Table 9

The Challenges and Concerns of Implementing Lesson Study

Participant	Challenges	Concerns
MT1	Making sure that the students were on pace to be ready for the lesson on the date that we chose.	Having the time to do it and keeping with the pace of the curriculum.
MT2	It would be difficult to be invited if you had not participated in the planning	Sharing benefits of lesson study with others who do not know about it
ST1	Finding the time to research reading passages and write sessions. Time to meet with the group.	Time to plan. Picking a topic.
ST2	The room constraints are a challenge. The large class is a challenge, especially certain individuals. Time constraints in being able to meet with other lesson study groups.	Time issues and room constraints since this is not something that I have a lot of control over.
ST3	At first, to try and figure how I could contribute to the lesson.	I think the most difficult part for the teachers was to figure out the natural to use for the lesson.
L1	As a literacy coach it is part of my job to get involved and interact with classes so it was difficult to not interact with the students.	Having observers that focus on specific areas and the time to debrief.

The Possibility of Continuing Lesson Study

Changes in Teachers. After the lesson study, all of the participants were observed again in their regular classrooms with a focus on whether they had changed anything based on what

they had learned from the lesson study process. Most of them did exhibit some changes in their instruction based on what they had found through the lesson study, were concerned more about student performance, and collaborated with other teachers more often to improve their lessons. These tendencies illustrated that they had obtained habits that could make the continued implementation of lesson study without outside help possible. These teachers would be able to conduct lesson study by themselves, because they had established the fundamental concept of how to carry out lesson study within the high school setting.

Changes in instruction. The participants discovered several student needs via lesson study. The math group found that students' Algebra I skills were weak, and the science group found that their students' reading and analysis of scientific passages needed improvement. The participants attempted to change their instruction based on their findings. For example, MT2 provided specific review and steps for solving for 'x' in various equations. She went over each equation with the students and offered detailed steps with a laptop and projector. Students seemed to be satisfied with her strategies and asked several questions when they did not understand or follow what she was doing. She mentioned this at the post-project interview:

> It just-main thing-one of the things that it pointed out to us is how weal some of their algebra skills were, and so I tried to slide those-review in a little more. Um, and then I got away from it, because it's hard when you start getting to different things to keep doing that. Um, but just trying to solidify some of those skills that are stopping them from discovering (MT2, Interview II).

ST2 pointed out the importance being able to read scientific texts. Hence, she explained the definition of each single concept, such as concentrate morality, products, reactants, forward reaction, and reverse reaction. She said that she would carry out lessons similar to the research lesson in the future:

> Um, well, number one, that I would incorporate, like I already said, those-that kind of lesson study that we did, that lesson, for sure next year and hopefully add to it. And

> maybe do it in conjunction with MT1 and MT3. I don't know what their feelings are. I'll probably use MT1's, and he might use mine. So we each have double the number, then. And then, um..um, just to be …be able to be detailed in what you plan out. How you transition, and those kind of things. I think that's important. So then-then you're not- then then it goes smoother (ST2, Interview II).

More concerns about student performance. As lesson study is student centered, student performance is paramount when they preparing the research lesson plan. This helped the teachers become more anticipatory of how students would react and respond to their instruction. For instance, MT1 noticed that students had not understood a concept due to a lack of skills; she had tried to look at the problem from the students' point of view. She addressed this issue during her second interview:

> Um…I think, um…looking at why we're getting the problems wrong. And, like, realizing that this is—the new material that they were taught, is it the concept, or is it the—the skills to get through it. And being able to separate those two. That was really obvious in the lesson study. That they understood the new material, which was how to find *a*, it's just that they couldn't physically do it, when they plugged the numbers in. So trying to distinguish where they're having the problems. Instead of just saying, "Oh, they don't get it" (MT1, Interview II).

Similar to MT1, ST2 indicated her students' weak math skills when she taught them about equilibrium. Students struggled with using a calculator to get answers. She observed why they were having a hard time and found the specific step which had led to the confusion. She then used a program called SmartView to show them how to use the calculator, and the students were then able to figure out how to use the calculator to get the answer. She discussed this scenario in her second interview:

> The thing is, they—it's different enough from $ax + b$ that having chemistry symbols in there really throws them off. So that's why I say, "Go ahead and put the numbers in, if you want. Go ahead and put an *x* for what we're trying to solve for, if you want." And then I try and make it—you know, and then automatically, we just automatically cross-multiply, whether you really need to or not, but I find that with them, it just works out better. If there's a denominator, cross-multiply. You know, so, I don't know. It's…I—I always feel like their ability to apply math is one level behind the math that they're in. So if they're in Algebra I, they're kind of behind—they're not really up to snuff in applying

> Algebra I skills. If they're in Algebra II, they can apply math in science at the level of Algebra I. And then it kind of washes out when they're in the higher math, like Calc kids can do calc. In—because we do that in kinetics. And they can handle that. And it's more of a "Wow, there is a real application for this." But at this level, it's—you really, as a chemistry teacher, you're a math teacher, too. Because, like, they're going to have to learn algorithms—next chapter, and I'll teach that to them before they'll get that in math (ST2, Interview II).

MT3 also mentioned that she let students have some time to figure the problem and solve it on their own. This allowed them to be main players in the classroom.

> And it just reminded me that I have to let the kids struggle with some of the content. You know, I'm still tempted to bail them out when I feel like they're struggling, and help them. But the lesson study reminded me that it's good for the kids to kind of…struggle with the concepts for a little bit. That they eventually do get there. Um, maybe with a couple hints, but, you know. I'm still tempted, like I said, to do the teacher-led thing. You know. [laughing] So lesson study was a good reminder to kind of leave them go (MT3, Interview II).

More time to collaborate with others. Most participants mentioned the benefit of collaboration with others and observation of their classrooms as leading to insight into various teaching circumstances. Thanks to this benefit, they tried to discuss what they thought about teaching and learning with an open mind. To support this, ST1 pointed out the helpful attitude among teachers based on lesson study experience:

> Um, I think, just…I think just realizing that…that teachers can help each other, um…through observation like that. Through coming in and helping each other—pure observation. Um…I think that, in terms of my instruction…it helped me to realize that I—my delivery, or my…um, standing there, giving them notes—that there's other things I need to incorporate, as well as that. You know, I think there's a place for everything, but it's so easy to get just back into that same habit of, you know, here's—here's the material, tell them about it, and then you give them a quiz or an assessment…to see what they got, but I think that there's more things that can be done. You know, more individual learning, more…um, student-centered learning—instead of being, you know, teacher-centered (ST1, Interview II).

Moreover, ST2 talked with the math department about the problems with using calculators after she discovered the students' problems:

> Yeah. I've talked about scientific notation, and I talked about calculator instruction (ST2, Interview II).

Hence, she was able to address the needs of her students by collaborating with the math department as well. In the same sense, MT1 brought the issue of probability up in her department meeting, because she noticed that her students had not previously learned about probability, although they needed it for Algebra II. She mentioned that when her department had changed the curriculum, probability had been eliminated. However, thanks to her observation of her students' needs, it was added in again for the next year's Geometry class. Students would have a better sense of probability in her Algebra II class the next year.

Similarities between the department meetings and the process of lesson study. The high school where this case study was conducted had several department meetings to provide professional development time for teachers (usually once a month). These meetings were observed in order to find any similarities to lesson study. The math department meeting was observed once, because there was one independent meeting about continuing with the new Algebra II textbook. During the meeting, the teachers reviewed their pace for the new curriculum, scheduling for tests, and other issues that they had for teaching Algebra II.

The science department meetings were monitored several times since there was no specific individual meeting time for the group of chemistry teachers only. However, there was a small group meeting time for each subject group (e.g. physics, biology, chemistry) to discuss current issues, semester plans, questions about the test, science laboratory schedules, and other concerns about teaching science.

Math department meeting. A meeting just for the Algebra II teachers was held on November 4th, 2008, because they had adopted the new textbook. A total of six teachers (two males and four females) attended this meeting, with a five-part agenda: (a) review work done on

the Chapter 2 tests--both team tests and individual tests; (b) review and discuss Chapters 3 and 4, including taking special note of checkpoints –check pace for finishing Chapter 4 by the end of the first semester (if it was too tight, they would decide if there was anything in these chapters that could be condensed or cut); (c) write a final exam and review it; (d) if time, begin writing assessments for Chapters 3 and 4; and (e) talk to F3 about the lesson study (for those who were participating).

Following the agenda, the teachers looked at the materials and checked their pace first. MT1 shared her teaching experience of the previous day, in which she had started to teach Chapter 3. She had taught 3.1 on November 3rd, and it had been a good lesson for most students to discover the concept for themselves rather than from direct instruction. Next, they had discussed what the students needed to know about Chapter 3. For example, they talked about compound interest and simple interest. MT1 explained that simple interest was arithmetic, but compound interest was geometric. Also, they solved some Chapter 3 problems together to make sure they knew how. One teacher asked MT2 how to solve an exponential equation, so she demonstrated how to solve it.

After the first break, they discussed Chapter 4 and examined materials and hands-on activities together. MT1 tended to lead the discussion, because she had had experience with the CPM curriculum, so she had strong opinions, but she was flexible as well. While they were working on an activity about diameter and mass, F3 asked them about the distinction between mass and weight. They looked carefully at what the textbook said about it and decided to ask the science teachers to make sure.

They had a second five-minute break and reported what they had discussed to MT3, the math department head, when she stopped by. They finalized the math concepts of the first

quarter (e.g. domain and range, intercepts, investigating functions, f(x), solving systems of equations, sequences, exponents, multiplying binomials, factoring, exponentials, and quadratics).

They discussed the final test after lunch. They chose questions and solved them in order to make sure they would work. MT3 told them what topics the students needed to know for the final test and advised them about teaching concerns related to school requirements. In addition, they tried to make their schedules clear for the first semester.

The teachers needed more time to discuss the final test, so C1 said that if they needed time to discuss it after school or outside of school, the school would be willing to pay for that time. They decided to meet again on November 18th to finish the final test.

Science department meeting. Several science department meetings were observed, and they had very different formats. The first meeting was held on October 22nd in ST1's classroom, ST1 being the department head. They were all white teachers (eight females and seven males). They discussed issues and concerns and following a eight-part agenda: (a) new classrooms, (b) setting days for next year, (c) the ACT, (d) lab updates, (e) workshop conferences, (f) periodic journals and magazines, (g) announcements from ST2, and (h) small group discussion.

During the small group discussion, teachers were supposed to discuss several issues (e.g. semester exams, curriculum updates, upcoming labs, suggestions and problems, discussion report, and the first quarter). The small group meeting of the chemistry teachers was observed for this study, since the participants in the science lesson study taught chemistry. They (one female and two males) checked their pace first; one teacher seemed to be behind the other two and wondered why. They discussed issues about "spectrum tube stuff," "power sources," video clips and worksheets, the semester test, physical classroom locations (far from each other), communication methods (email every Friday), instructional skills (PowerPoint slides for outlines, periodic table),

lab assistants, and suggestions for the next meeting (more time working in small groups, less time for whole group meetings), and curriculum goals.

The second science department meeting was on November 19th. The key topic at this meeting was the ACT. C1 and L1 were invited to describe how the ACT needed to be considered, because its indication of student improvement reflected on school improvement. They focused on the importance of the ACT test and the emerging needs of integrating reading into science. L1 stated that science teachers needed to examine questions and passages every day since the ACT was about cause and effect questions; sometimes it has harder questions, but once they started memorizing it, the ACT became a test of memorization. She elaborated on how to help students: look at ACT passages and think about what they were doing in the classroom, preparing ready-made reading passages, focusing on strategies instead of content itself (e.g. cause and effect), and making every question related to the reading passages. Following her guidance, thy looked at the ACT data. After this activity, they had small group meetings.

Finally, one of the science department meetings was a lab organizing day. The teachers met in the science laboratory to check all the equipment. This meeting was a first-time event for them. They worked in pairs or individually, taking everything out of the drawers and then putting them back into the right places in a certain order, checking for instruments in need of repair or replacement.

Afterwards, they reconvened in a classroom and followed a discussion agenda: door locks for the computer lab, the preview day for incoming freshmen, passing the lab AT exam, creating a list of things the needed for the next year, new course proposals, ACT review, building remodeling and parking spaces, spring break, department chair meeting, and the schedule for PSAT and pre-ACT tests.

After the whole group meeting, the teachers had small group meetings. The chemistry teachers discussed test items, scheduling, checking homework, and current student issues (e.g. lack of motivation or math skills).

Similarities to the lesson study process. There were several ways in which the department meetings were similar to the lesson study process, based on an analysis of my observations. First, thinking about student performance enabled teachers to think about how to teach effectively, which is similar to lesson study. For example, one teacher in the math group pointed out that students understood the concept of "root," but they did not know how to put it into the calculator. Also MT1 said that students could substitute numbers in equations, but they could not solve the equations. As a result, they decided to teach students how to use the calculator more carefully. In addition, the science group reorganized all of the materials for students and themselves in order to provide better circumstances for the students.

Next, they discussed content knowledge along with students' needs in the textbook. As mentioned earlier, the math group attempted to confirm the distinction between mass and weight. The chemistry small group talked about the mole project, the icosahedrons on the periodic table, activities with the periodic table, and atomic radius during their discussion time.

Third, because of the first two similarities, the teachers developed beneficial instructional skills and techniques. The math group reviewed certain hands-on activities with the textbook to confirm what they needed to know in order to teach them. They also tried to find sufficient resources to introduce the concept of "quadratic" (e.g. a donut activity, a nice golf shot). However, they focused on the content of the new textbook rather than how to deliver the lessons because of the newly adapted curriculum. The science group discussed how to make

worksheets based on video clips, how to use PowerPoint files, and how to engage students in the periodic table.

Fourth, teachers thought about connecting their lessons to their teaching goals. For instance, the math group examined the learning objectives since they noticed the need to think about the order of the activities or the connection between the lessons in the unit. They figured this out first, rather than discussing the content of activities further. The science group watched a video clip on Youtube about using technology, since one of their department goals was to use technology in the classroom. After watching this, ST1 mentioned that the competition for students would be global, and that India had more honors students compared to the U.S.

In summary, it would be possible to work lesson study into the department meetings because of the similarities between them. The department meetings bore a striking resemblance to the lesson study planning meetings. Teachers focused on students' performances, content knowledge, and instructional skills and techniques, as well as the connection between lessons and teaching goals. Although the department meetings did not show similarities with every step of the lesson study cycle (such as delivering the lesson and debriefing), teachers exhibited the natural behavior of thinking about teaching and learning. Lesson study would lead them to think about teaching and learning more effectively in order to improve their instructional knowledge with well-organized collaboration.

Summary

A lesson study was implemented in a unique high school setting with sufficient help from the facilitator and active participation. The math group conducted their lesson study in the fall of 2008 and the science group did it in the spring of 2009 after changing their topic for the research

lesson. The math group had two planning, two deliveries, and two debriefing meetings in order to implement lesson study. During the planning meeting, teachers chose the topic related to their teaching goals and current students' needs, and scheduled specific dates for lesson study. Also, they developed a research lesson plan with sufficient discussion of content and instructional skills for better delivery. They determined research themes and observation questions following the steps and the examples of observation questions presented by Lewis (2002).

During the delivery meetings, teachers who taught the research lesson attempted to follow the lesson plan appropriately, and others including a facilitator observed teaching with their observation questions and noted what they observed on an observation template developed by the facilitator. Teachers provided reflections and feedback based on their observations while debriefing after each delivery. They tried to develop an effective research lesson plan according to their discussion during the first debriefing and thought about the benefits or challenges of lesson study and the implications for their future teaching during the second debriefing.

However, the science group had four planning meetings instead of two because they switched the topic of their research lesson after discussing the relationship between their teaching goals and the theme of the research lesson plan. As with the math group, the science group had two delivery and debriefing meetings. Despite sharing an initial lesson plan for the first planning meeting, the teachers realized that they needed a different topic for the research lesson based on their teaching goals. Hence, they decided to think more in order to choose another topic for the research lesson.

They usually scheduled a tentative time for lesson study during the second and third planning meetings. They confirmed the topic of the research lesson plan and finalized their

schedule for lesson study at the third planning meeting. During the delivery and debriefing, they did the same things, within the different context, as math group did.

As a result, they were able to consider the practical connections between teaching goals and their teaching, and expanded their insights to perceive their students' needs and their instructional knowledge based on the observation. They collaborated actively in order to discuss the content knowledge and instructional skills, to share their experiences and concerns, and to develop a beneficial lesson plans for students.

In order to implement to lesson study, I played an important role for teachers as the facilitator. I provided practical and efficient help for them such as preparing templates for delivery and observation and consent letters for students and parents, informing teachers of the details of what lesson study is about and the process of lesson study, coordinating schedules, resolving the emerging issues of implementing lesson study, and being friendly and supportive in order for teachers to follow all the steps of lesson study.

After the lesson study, participants demonstrated changes in their teaching based on a newfound view of students' needs collaboration with other teachers. These changes led participants improve their teaching strategies for considerations on student performance with helps from each other in order to make their lessons beneficial and effective for students.

Finally, a comparison of the regular department meetings with the lesson study process showed several similarities, indicating a possibility of incorporating lesson study into teachers' regular practice. There were several department meetings to provide professional development time for teachers. During the math department meeting, math teachers reviewed their pace of teaching the new curriculum, the scheduling of tests, and other issues that they had teaching algebra II. The science department meetings had a whole group meeting time to discuss the

concerns and issues in the science department along with an agenda. They also had a small group meeting time for each subject group to discuss current issues, semester plans, and questionnaires about the test, the schedules for science laboratories, and other concerns about teaching science. The department meetings were similar to lesson study planning meetings because they discussed the purposes of lessons, students' performance, content knowledge and beneficial instructional skills and techniques, and the connection to teaching goals.

Chapter 5

Discussion and Conclusion

Implementing Lesson Study in a High School Setting

This study examined the implementation of lesson study as a method of professional development in high school mathematics and science settings after the initial funding had ceased. It focused on teacher implementation of lesson study, student performances during the research lessons delivery, the context of math and science departments, and actual content discussed by teachers during the planning research lessons. This study will hopefully allow others to (a) find ways to implement lesson study in various school settings as a collaborative learning process, (b) recognize what constitutes practical and efficient help from facilitators, (c) focus on student performance, and (d) find ways to continue lesson study without funding.

Several elements contribute to the successful implementation of lesson study: previous positive experience with lesson study; support from the school; lesson study facilitators; dynamic participation from teachers; a recognition of the benefits of lesson study for teaching and learning, as well as the ability to make connections between teaching goals and practical teaching; an awareness of students' performance and behavior; and respect for the perspectives of others.

There are also several concerns that need to be addressed when lesson study is employed as a method of professional development: misconceptions about what is lesson study is; insufficient time to implement lesson study; varying levels of participation in the lesson study; challenges related to the classroom context, and the rigidity of the steps of the lesson study process.

Factors that can lead to a successful lesson study. According to Lewis (2002), the cycle of lesson study includes planning, a first delivery, debriefing, a second delivery, and then another cycle of the same process. This provides sustainable loops for researching about teaching and learning. Although this process cannot be incorporated into every lesson, lesson study demonstrates how teachers can teach the research lesson as an example of improved instruction for application to their daily teaching.

As mentioned by Lewis (2002), teachers review existing lessons when they develop the research lesson. They study previous implementations of lessons in order to build more effective lessons for students at the planning stage. This helps them to consider the connection between their lessons and long-term goals and to develop a well organized and effective research lesson plan in anticipation of students' performance. It also facilitates teachers' discussion of their content knowledge and instructional knowledge in order to develop more beneficial lesson plans for students. It provides time with teachers to create observation questions that fit the themes of the research lesson. These questions lead them to focus on what can be improved not only in the lesson plan, but also in their overall teaching.

Next, teachers see learning at the students' level through lesson study (Lee, 2008). In order to understand their students' perspectives, teachers teach the research lesson first and revise it after feedback and reflection based on observations of the lesson delivery. While one teacher teaches, the other teachers closely observe the delivery so they can provide more detailed observations of the students' performance. More eyes are helpful for improving instructional knowledge.

Finally, the department meetings indicate that the teachers in this study were attempting to be aware of teaching as part of their annual department goals. However, they were not

successfully incorporating these goals into their regular teaching. For example, once the science department noticed the importance of reading for the ACT test, the teachers who were not participating in lesson study modified their lessons to include reading activities, but it did not work as well as they expected:

> Um, the biology group, we were basically looking at, um—hold on. [Interruption] Okay. So where were we? Um, the biology group that we had, it was something that we were presenting, just a critical thinking, um…kind of like a study—a strategy system for reading comprehension skills. And I had—we're using—we're looking at the Gretchen Courtney model. So she has her own pamphlets and how she does things and steps. So I tried to combine that into, um, the biology teachers in their classrooms, and using their literature, and they would pick the, um, readings that they did the skill with. So it was sort of like graphic organizers, um, with predicting. And when we—when it came to observation time, there really was a hard time with teachers wanting to schedule it. They really kind of figured, "If I wait till the last minute, we'll get out of it." So, I mean, but it was something where I wanted to be flexible with their schedules. So they—initially, what happened was, they were kind of told, "You will do this." They didn't really volunteer for it. So I had some resistance on that end. Whereas with the lesson study, every teacher had a reason for doing it. And they had their own reason and their interest in their study and perfecting their craft, and in—in this case, it was, "I'll do it because…I'm a non-tenured teacher, and you're telling me I've got to do it." So I think it was something that the lesson study group was really ready to get insight and better their practice. And I think the other group…liked getting a new strategy but didn't want to be forced to use it or reflect on it or think about it. And they didn't really get any scheduled time out of class to get together and reflect as a whole group. It was all one-on-one, once we went past the initial presentation. So I think, you know, the next time around, you know, I didn't want to pull them out of class another day, because there was so much going into the design that we didn't want to pull them another time, but then during their prep time, when I figured they would meet with me, they were really kind of resistant to meeting. You know, it's ten minutes and you're done. And it takes longer than that sometimes. And sometimes it's not just what I'm seeing. That's the other component of the lesson study. In the lesson study, you had two or three teachers observing at a time. In the biology group, it was just myself observing. So, and that's where, it was kind of like mine was the one word. Mine was the only reflection that they saw. And next time, that's one of the things that we're putting in, is, we want a group of teachers to be evaluating, not just—or observing. Not just one person (L1, Interview II).

L1's experience showed how the lesson study approach worked better for connecting the lessons with the teaching goals.

Even though this study did not focus on how the students performed, students were observed with specific foci in mind when the research lessons were delivered in order to reveal the effectiveness of the research lesson. Student observations were essential, since students are viewed as the center of teaching and learning, in the lesson study process. The following observations occurred during the implementation of the lesson study:

> That, uh, African-American girl—the tall one? She—she didn't seem like she was willing to—to share. I don't know if she didn't understand it, or she just felt uncomfortable with sharing the information, or, I don't know (ST1, Debriefing II).

> Because they wanted him to explain it to them. And then the group by the door, um, they got it. And they had one kid that was struggling, and they explained it to him, and they were fine. And then that group in between them, S8 kind of did all his work on his own. The one guy that got up to go to the bathroom, he said he had mono, so, like, he shouldn't have to do anything. I'm like, "You're here." And then the girl finally got her stuff done, so I don't think he ever got the stuff done. Just like the girl in your group never actually got her stuff done (MT2, Debriefing I).

Lesson study enables students to engage in learning actively because teachers create research lessons for better student performance.

Furthermore, lesson study helps to build natural discussion about practice through the sharing of ideas, resources, and experiences (Lewis et al., 2004). Although all of the steps of lesson study allow for open-minded collaboration, the debriefing session especially provides a comfortable and natural space for sharing what teachers think about teaching and learning based on their reflections, observations, and feedback. L1 emphasized teacher collaboration:

> Yeah. And that—and that goes hand-in-hand with my biology. Was that, I think, coming up with the specific areas, um, you did a tremendous job coming up with those areas, and the teachers coming up with them. I think it's something that, you know, I'm wondering how do I get…teachers to start making that list? How do I get them to come up with more than five things to look at? You know. Um, and also wanting to do that. And then the debrief time, again, was just scheduling, and that time to get them out of classes to debrief. When, I mean, they're just kind of like, "Hey, yeah, I took it, I did it. I'm done." You know? I mean, we've really got to incorporate, "Okay, where do you go from here? Now there's a follow-up. Let's look and see what you've changed." And it's got to be a—a time frame. And that was one of the things that I liked about the lesson study, was

> that we saw things in one teacher's room, and tried to modify those things in the practice. So it wasn't the teacher, it was this is how it's being administered. That we were able to see change in the second thing the very next day. It wasn't something that, if it's solely put on the teacher, we're going to observe Teacher A, we notice these things, so we'll come back and observe Teacher A again to see if those things have changed. Now it's assigned to the teacher. So it's more their methods that they feel like they're losing out on. Whereas if it's a counterpart, and they're working on it, they will both get to see both sides of it. Not just doing it, but also observing it. And I think that's key. I think getting that set up, and getting that mindset there is just—that's—that's the key to the lesson study that makes it so successful. Is because it's not…one particular teacher only being evaluated, or just one, you know, looking at someone. It's a group of people who are professionals that come together and look at methods that work with kids (L1, Interview II).

Lesson study results need to be disseminated in order to develop lesson study communities (Perry & Lewis, 2008). Since lesson study is a relatively new approach to professional development in the U.S. context, more opportunities for introducing lesson study are needed. Even though several lesson study research teams are working actively in the U.S., there are currently not enough to build lessons study communities nationwide. Once lesson study has become established in U.S. culture, participants will be able to continue lesson study independently. L1 addressed the importance of documenting what teachers had done during the lesson study in order to reuse the documents when they needed to.

> Yeah. Absolutely. I mean, it was one of the things that I wanted to talk to you about. The way you did the observation and the framework that you had laid out for us. I would love to use that as a template and start working with it. Because I really think it gave teachers a clear focus that you didn't have to go through and explain every box to us. It was self-explanatory. It was so easy to use. And it was literally a checklist for some of us. And there was plenty of room to write your notes if you needed that. And that was something that, for some of the reflective, or observational tools I've used in the past, that I've just kind of done, they've just been empty boxes. So there's been no direction for people to really write down things, or they'll focus on, you know, maybe one student in the back of the class, you know, not doing what they were supposed to. And we talked about that, how, you know, find out specific things that kids are saying. Because sometimes, you know, we'll just chalk up, you know, as educators, we have a tendency to say, "Oh, you know, that kid wasn't with it today," or "The kid didn't care." But if you have that small group in that quadrant listening to what that kid's saying, you might find out the kid's getting parts of it. There's things that are missing that the kids trying to work through. That's a totally different look at that kid. And a totally different look at what your lesson

> was. Because if the same groups are having that gap in their learning, then you know where something's going on, and you can strengthen it next time. So, I mean, that's awesome. I definitely want to use that again. (L1, interview II).

In addition, the math and science content was discussed interactively and at length during the planning of the research lessons. As outlined in Chapter 4, the teachers examined the chapter related to their teaching goals and chose a topic for the research lesson. They discussed how to deliver it effectively: precise content, instructions, previous teaching experiences related to the topic, and anticipation of students' responses. These discussions allowed them to be confident in their content knowledge as well as their instructional knowledge.

Roadblocks to successful lesson study implementation. During the lesson study, the teachers' expectations of student achievement were based on their own predictions, rather than on their observations of students' needs. As a result, the research lesson plans did not fully take into account student performance. Interestingly, the following interview illustrates the example of the gap between the students' and teachers' expectations in terms of the connection between math and science.

> Oh, yeah. Um…it—the—what we—what I notice is that students are resistant to taking what they learn in math or algebra and bringing it into the science classroom. Um…a lot of the things that they know how to do, they don't…make the connection to science. And when we ask them to do those things in science, it's—it seems like it's a challenge for them. So we end up re-teaching a lot of basic algebra stuff in—in the chemistry, um, because that connection doesn't get made. Or the carryover isn't there, or, you know, the cross—across the curriculum isn't being made. Um, and I just…maybe—maybe we need to communicate more with the math department on that, and—and know what their curriculum is for the different levels—and know what students have. But there's also a wide range of abilities in the class that we have, as far as math goes. Um, it is a lower…expectation for math than a regular chemistry class. Um, but we did do…some of the necessary stuff, and we tried to make it a little less, um…less painful for them. But there's a lot of students that, as soon as they see any kind of math, they just shut down, because they have that phobia. And, uh, that's always a challenge to get them through that (ST1, Interview II).

However, if teachers focused more on student performance rather than their own expectations, they would be able to improve their practical instructional skills for student-centered learning through more lesson study practice.

After the lesson study, the teachers seemed to have improved their instructional skills based on what they had learned from the process lesson study. However, they also seemed to need a clearer understanding of student-centered learning in order to appreciably improve their instructional strategies. Even though they talked about student-centered learning during the lesson study planning meetings and tried to achieve it in their regular teaching, their teaching inevitably returned to a more teacher oriented approach.

In fact, as MT1and MT3 mentioned during the second interview, there is no time to discuss any specific lessons during the regular teachers' meeting times, such as the department meetings:

> We don't…talk specifically about—we don't talk about specific lessons in our department meetings. We talk about general—more general things. Because we're all teaching different, um…you know, different classes, and there's fifteen teachers. So we don't usually have those at all. Unless it's a brand new curriculum. Then we'll need to help implement the new curriculum, but on a regular basis, we don't do that (MT1, Interview II).

> Um…I think it's more difference, because the department meetings, we don't have time to hash out the particulars of lessons (MT3, Interview II).

Hence, teachers need more time to discuss specific lessons for student-centered teaching and learning. The teachers involved in this project had the lesson study planning time, but they needed even more time to think about and discuss their teaching. As Lewis (2002) states, Japanese teachers spend much time planning the research lesson, since that time affects their regular teaching in a positive way (p. 62). Thus, teachers should have more time to plan the research lesson, which will in turn improve their regular instruction.

Students need to be observed more in order to see whether they are involved in learning or not. As ST1 mentioned, teachers need to observe and debrief other teachers as a regular practice.

> Oh, yeah. I think definitely that would help. I don't know that how—I don't know how much it would help if you didn't have a focus. You know, and a feedback. You know, for them just to go in and observe, and never talk about it again, or never get back to it again, I don't think that would be useful. I think it would just be an exercise. I mean I—I guess maybe there would be some value in it. You know, I think it's always good to see other people teach. But I think it would be even more beneficial if, like, if there was a way to get feedback and, um, debrief about it (ST1, Interview II).

Observation led to different points of view on teaching and learning. Observation alone is not enough, of course--teachers also need to discuss their observations in order to improve their instructional skills and to understand learning from the students' perspectives.

Lesson study provides an opportunity to observe other classes closely with a specific focus. However, the teachers in this study did not fully understand the observer role or the purpose of observation for lesson study. They needed specific details about how to make observation questions and how to observe properly. As a result, the student data, including their discussion, questions, comments, and other performances were not appropriately collected by teachers. Important data which may have enabled teachers to improve their instructional skills was lost.

Above all, time is most daunting challenge of lesson study, even when teachers recognize its benefits for their teaching. ST1 emphasized the issue of time as a big challenge to the implementation of lesson study:

> Well, when—when you do the lesson study, and you have to get, uh, people out of their classes to do the debriefing, and—and the planning, that's hard for a lot of people to get out of class. So…Some people. Some people, yeah. But no matter who you are, if you're out of your class, it's a struggle. It's a challenge. I personally feel like the times that I'm taken out of class, I don't take that lightly. You know, I don't get out of class for every opportunity I get. I—when I get out of class, it's for something that I feel is more

> important, you know, for the big picture. You know, I know that that class is not getting, maybe, what they need for that day, but in the grand scheme, I think it's more important that I'm doing what I am doing. Um, so I guess, in order to minimize the impact on the individual classes, maybe during some—some department time that is already planned, that you're already going to be out of class, that'd be the time to do it. Like, during our monthly meetings, or if we can maybe increase that, um, to…maybe a couple more times a month, um, where everybody, you know, doesn't have to get a sub, um, then that would be more productive, I think. Um, and next year, they're planning on doing some early, um, or late start days. Which, we did a couple this year, but they're going to start later in the morning. Um, and I know some schools do a weekly, like Monday, the students don't come until nine o'clock, and the staff starts at eight, and they meet for an hour. Before—at the beginning of the week. That way, everybody's there, you can kind of start the week off, and you know, it's not a disruption. And if we had something like that where we could plan these kinds of things, that would be good, too. And I think you need a commitment from the teachers involved to do what it takes, you know, to spend the time. You know, if it does take a little bit of time outside of school, they need to be willing to do that (ST1, Interview II).

Also, the physical location of the classroom was a challenge for lesson study, as ST2 mentioned:

> Well, ideally, everybody's located in the science wing, number one. Um, number two, you are next to the people who teach similar subjects, so that if you need to float in or out of a room—it's much easier. You don't necessarily have to go through administration to get a sub and all that. The other thing is, you don't—you know, I have a lot of—you have a lot of pressure to get through the material, and if you're out of your classroom, you're losing a day to get through the material. And that's—that's another thing. But if you knew that somebody was taking over your classroom that could teach the material that day, because you were within close proximity, and it would just work out, because it was their prep period, and you were going to do the same for them—stuff like that—then it would work. Those kinds of things (ST2, Interview II).

These contextual issues need to be resolved for further lesson study implementation.

What the researcher learned. As mentioned, a facilitator is a key factor in implementing professional development programs. Facilitators help teachers to understand the main themes and goals of programs, to improve their instructional and content knowledge, and to improve their practice. When facilitators know their roles before implementing any professional development program ((Bush, 2008; Perry et al., 2002), they are able to develop the content and agendas for the programs (Le Fevre and Richardson, 2002; Perry et al., 2002; Sandell et al., 2004) with an enthusiastic, flexible, respecting, patient, persistent, and caring attitude ((Bush, 2008;

Lindqvist and Reeves, 2007). They provide appropriate facilitation while implementing the program, and they deal with emerging challenges (Le Fevre & Richardson, 2002).

Lesson study relies on the facilitator because its results contribute to a shared professional culture instead of professional activities (Watanabe, 2002). Facilitators should fully understand what lesson study is, have experience with lesson study, consider the challenges and complexity of lesson study, appreciate the challenge of importing lesson study into a different culture, and help establish lesson study by offering practical experience.

Similarly, as stated by Perry and Lewis (2008), leaders of lesson study continuously assist teachers by providing crucial resources, including "protocol, lesson plan template, and observation forms" (p. 21). Any leader can be a facilitator of lesson study. Although lesson study leaders tend to be teachers or outside experts who introduce lesson study for the first time into a school setting, once the teachers of the school have adopted lesson study as a habit, these experienced teachers can become lesson study leaders.

As the facilitator for this study, I studied what I needed to prepare and consider supporting the participants in their effort to implement lesson study without funding. My previous experience with lesson study in Korea affected my perception of what American teachers could or could not do in the process of lesson study. For example, I expected that they would be able to choose a research lesson, based on their teaching experience. However, they did not even understand how to make a connection between their teaching goals and the research focus. As a result, I realized that I needed to review all steps of lesson study, and I prepared documents with concrete explanations.

Firm scheduling and timelines for the implementation of the lesson study was another element that would have allowed for smoother progress. When I provided tentative schedules,

teachers set their schedules easily. Also, my role as a bridge for obtaining support from the school was very important for importing lesson study into these teachers' classrooms.

In addition, I learned that specific directions for teachers were important. For instance, most of the teachers were confused about how to behave when they observed the delivery of the research lesson. Hence, some of them interrupted the natural flow of the research lesson. Afterwards, I clarified the exact role of the observers, which prevented a second interruption, but I should have informed them about this earlier.

Overall, I learned what teachers could and could not do by themselves to implement lesson study. Once they fully understood lesson study, they could implement it independently. However, they would still need support from the school in terms of scheduling and resources. The experience of lesson study changed the teachers' perspectives on student learning. The teachers became more student-centered, more interactive, more considerate of students' needs, and they improved their instructional strategies. In spite of challenges, such as lack of time and differing circumstances, lesson study involved teachers in professional development to improve their instruction.

Possibility of Continuing Lesson Study

Factors that increase the possibility of continuing lesson study. As mentioned, the possibility of continuing professional development is related to the program's level of organization. Wilson et al. (1996) claim that professional development programs need practical and continuous support, practical examples of teaching, constant reflection, various perspectives, and an awareness of the practitioner in teaching. Also, Klingner et al. (2004) state that professional development programs need to be research oriented, to provide proper support, to

assist improving knowledge, and to assess their effectiveness. Tafel and Fischer (2001) illuminated the factors for sustained professional development. Professional development needs: to encourage rapport among peers, to allow for their autonomy, to provide for reflection on their teaching, and to allow active collaboration.

These points which contribute to the sustainability of professional development have several similarities with lesson study. Although lesson study work is time-consuming, it allows, among other things, for teachers to have a clear idea of their strengths and weaknesses (Fernandez & Yoshida, 2004), and enables them to be reflective on their teaching and students within a collaborative environment (Fernandez, 2005). Lesson study helps teachers make a connection between "educational goals and standards" and daily life in the classroom (Lewis, 2002; Takahashi & Yoshida, 2004). It enables teachers to discover goals for teaching and student learning, so it leads teachers to be more interested in classroom practice and motivates them to have a confident attitude towards personal growth (Fernandez & Yoshida, 2004).

In addition, lesson study fosters data-driven teaching improvement and student-centered teaching in order to reach many students (Lewis, 2002). Since lesson study focuses on student learning, teachers are able to observe students' thinking and learning (Fernandez, 2005). Takahashi and Yoshida (2004) claim that it enables teachers to "learn to see their practice from the child's perspective" (p. 438). In addition, lesson study facilitates the construction of "grassroots" teaching improvement and fosters effective teaching for the improvement of student learning (Lewis, 2002). Therefore, lesson study is an efficient method for sustaining professional development programs in any school setting.

Factors that decrease the possibility of continuing lesson study. The aforementioned misconceptions of importing the idea of lesson study affect the success of its implementation

within the U.S. context. First of all, as Lewis (2002) mentioned, teachers still think that lesson study is only about one single perfect lesson rather than whole files of lessons based on the curriculum. If lesson study affects only one specific lesson, it does not appear to be very useful. Similarly, Lewis (2002) addressed other misconceptions of lesson study--lesson study is all about planning, leads to the collection of abstract data, requires an inflexible script, revolves around the opinions of experts rather than the ideas of teachers, or is purely about research. Such misconceptions prevent teachers from becoming involved in lesson study with an open mind. Therefore, teachers need to be correctly informed about lesson study so that it can be implemented successfully and sustainably.

As mentioned earlier, time is a big challenge of lesson study, because teachers have a lot of things to do besides teaching. For instance, they may be coaches, department heads, participants in professional development programs, and so on. These extra jobs mean that they are very busy, so they do not have much time to conduct lesson study even if they want to.

Moreover, some teachers are reluctant to leave their classrooms in order to observe other colleagues' performances, although they know the observation would help them expand their own point of view on teaching.

Lastly, even though there are numerous similarities between the process of lesson study and department meetings, it is not easy to institutionalize lesson study in a high school setting. Since high school teachers teach various subjects with different students in terms of developmental stages and grades, it is difficult for teachers to make connections within the school.

My view as a researcher. Through this study I attempted to determine the possibility of implementing lesson study without funding and of continuing the lesson study beyond the scope

of this study. Several promising results arose from this study, such as obtaining a clearer idea of the teachers' strengths and weaknesses, reflecting on their teaching and students, making a connection between teaching goals and actual teaching, considering student performance based on observations, collecting data from students in order to improve instruction, and thinking about student learning more often. However, several impediments arose as well, such as misconceptions about lesson study, the amount of time needed to complete a lesson study compared to other professional development approaches, various levels of understanding of how teaching should be, and very different circumstances in terms of what the participants were teaching to whom.

Overall, the gradual effort of changing and improving lesson study in order to overcome such challenges will benefit teachers' professional development program (Fernandez, 2002). Lesson study will assist in the creation of a cohesive network among lesson study groups (Chokshi & Fernandez, 2004; Fernandez & Yoshida, 2004). With continuous support from school administrators, teachers will be able to implement lesson study (Stepanek et al., 2007). Lesson study could be conducted by teachers independently, once they fully understand the process of lesson study and have experience implementing it with initial help from an expert.

Implications for Education

Five main points are needed for implementing a profession development program, based on a review of the literature. Professional development should: be on-going; offer qualified knowledge of content, instruction, and student learning; be standards-based; consider teachers' needs for their current practice; and encourage teachers to become practitioners. Since there is no single factor for effective professional development that impacts work strongly enough to

improve practice, the growth of professional development requires the harmony of all the factors addressed above.

The lesson study approach helps provide continuous, qualified, practical professional development. It also allows the connection of standards and goals to teaching and the possibility of researching about teaching. The following interviews show what teachers thought about their future teaching based on their experience with lesson study.

> Um…well, talking to other teachers about the lessons, and how it went for them. Um, we may not be able to observe each other, unless the administration does that. And then talking about what the skills are that the kids need for the lessons (MT1, Interview II).

> Um, the big thing, I think, is—is just the reflection of, um…you know, the process, and trying to reflect afterward on…what stopped them, and actually writing it down—the problems. So that next year, when I look at it, I can kind of remember (MT2, Interview II).

> I think…the lesson study that we did this year was with the CPM curriculum. And it just reminded me that I have to let the kids struggle with some of the content. You know, I'm still tempted to bail them out when I feel like they're struggling, and help them. But the lesson study reminded me that it's good for the kids to kind of…struggle with the concepts for a little bit. That they eventually do get there. Um, maybe with a couple hints, but, you know. I'm still tempted, like I said, to do the teacher-led thing. You know. [laughing] So lesson study was a good reminder to kind of leave them go (MT3, Interview II).

> Um, I think, just…I think just realizing that…that teachers can help each other, um…through observation like that. Through coming in and helping each other—pure observation. Um…I think that, in terms of my instruction…it helped me to realize that I—my delivery, or my…um, standing there, giving them notes—that there's other things I need to incorporate, as well as that. You know, I think there's a place for everything, but it's so easy to get just back into that same habit of, you know, here's—here's the material, tell them about it, and then you give them a quiz or an assessment…to see what they got, but I think that there's more things that can be done. You know, more individual learning, more…um, student-centered learning instead of being, you know, teacher-centered (ST1, Interview II).

> For my—mm…[pause]…well, just the lesson study in itself, I think is valuable to be a part of that, and I would encourage other people to participate in that. And, um…I would like to be a part of that and do it in other areas. I think it would be good. Like, everybody that's—it's—I guess it wouldn't even really—well, I guess the same area of science. It wouldn't have to be the same science class—Because I don't teach the science classes

> that ST2 and ST1do, but, like, um, all science or all math, I think they experience in itself is good. Um, also the amount of t—I'm think about what I observed as well, is the amount of time—the introduction, I know, with Jeanne, and that was, like, starting right away, and the second time around, they could have it set up faster, so some of the, um, instruction at the beginning went smoother and quicker and dividing into groups, how, ah, Jeanne did that was really good. Getting students in groups, and they were—had experience doing that, and changing the groups is kind of—well, the way she did that, as well (ST3, Interview II).

Based on these interviews, teachers had changed their points of view on teaching from teacher oriented to student centered and were aware of the value of lesson study, so they improved their teaching based on all the benefits they received through lesson study.

Implications for in-service teachers. Lesson study as a method of professional development can be introduced to any school setting. The first introduction requires experienced facilitators with a full understanding of its goals and procedures in order to maximize the effect of lesson study. After initiating lesson study and going through several cycles, teachers who have experience with lesson study can become lesson study leaders, which will enable sustainable implementation. Incessant support is the most important factor for professional development (Akiba et al., 2007, p. 382; Elmore & Burney, 1999, p. 291; Garet et al., 2001; Guskey, 1995). Hence, in-service teachers need to learn how to implement lesson study as professional development.

Second, teachers can participate in lesson study interactively and collaboratively to build knowledge of content, instruction, and student learning (Cochran-Smith & Lytle, 1999; Elmore & Burney, 1999; Wilson & Berne, 1999) since lesson study leads to useful discussions among teachers to address concerns. Also, teachers' dynamic participation in lesson study enables them to expand their perspectives on teaching and learning.

Third, teachers tend to implement lesson study for the practical goal of improving their instruction (Guskey, 1995; Seidel & Shavelson, 2007). Lesson study provides learning

opportunities for integrating outside knowledge into practice (McLaughlin & Zarrow, 2001). Also, it gives teachers more autonomy, because they can present their opinions as the results of research developed through their lesson study practice.

Lastly, teachers can become practitioners of research on teaching and learning via lesson study practice. As Putnam and Borko (1997) pointed out, teachers need to be very vigorous learners who can construct their own thinking and make meaning for teaching and learning. Teachers need to research their own practice and to reflect in order to improve their teaching. Lesson study allows them to be active practitioners with numerous reflections and feedback on their teaching practices.

Further research on lesson study. As Fernandez (2005) suggested, teachers need to learn about both lesson study itself and the benefits of implementing lesson study. This will reduce the gap between the U.S. and Japanese contexts, since Crockett (2007) points out that "Japanese teachers view teaching and learning differently than do U.S. teachers" (p. 614). As they become more informed, U.S. teachers will see cultural similarities through lesson study, despite the difference in context. This study examined sustainability in addition to the implementation of lesson study; future studies should consider other possible benefits of lesson study.

Secondly, although the role of lesson study facilitator was investigated in this study, it should be examined further in terms of providing practical resources. Specifically, the focus should be placed on teachers as leaders of lesson study. Once lesson study is established in a school setting and teachers implement it continuously, their role as leaders of lesson study should be examined.

Lastly, research on incorporating lesson study into department meetings will be needed in order to investigate the sustainability of lesson study. This study observed the similarities between department meetings and lesson study, but the lesson study was implemented by itself with no connection to the department meetings. Based on the findings of this study, future research needs to inspect the integration of lesson study into the department meetings.

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Appendix A

Interview and Survey Protocol

Participant Interview

Pre interview questions for teachers

1. What is your main teaching goal, if you have one?
2. Do you have any specific teaching goals for this semester or this year?
3. How would you define your role in the classroom?
4. How does your department generally support you in terms of teaching and learning?
5. Do you get a lot of support from your department? Do you wish you had more?
6. And how did the university partnership support you when you were working with them?
7. Did you benefit from working with them for three years?
8. What kind of support did they give you?
9. Did you need something that they didn't provide?
10. What do you think about lesson study in general?
11. What are your expectations for doing a lesson study?
12. What odd you think is going to be difficult about doing the lesson study?
13. So you have any specific needs you would like to tell me about for this lesson study?
14. Do you think your department and your school will support your doing lesson study for this year?

Post interview questions for teachers

1. Compare to your expectation before implementing lesson study, what did you get from the lesson study?
2. What is lesson study based on your experience?
3. What kinds of benefits have you received?
4. What kinds of challenges or constraints have you encountered, if there is any?
5. What did you learned from the procedures of lesson study?
6. Can you see the possibility of continue lesson study?
7. What do you think you can continue lesson study by yourself?
8. Do you think lesson study can be institutionalized? How? Why not?
9. Compared to previous experience of lesson study, what is your most learned from this year?
10. What kinds of help do you think efficient from me as the facilitator?
11. How can you define what lesson study is?
12. What has been changed after lesson study in terms of your instructional knowledge? Or pedagogy? Or your focus of teaching?
13. What kinds of learning from lesson study do you want to keep for your future teaching?

Interview questions for the coordinator

1. What kind of support did you get from the university partnership for previous years?
2. So are planning to find another project like that for the future?
3. So have you heard any feedback from teachers about the supports sponsored by the university partnership?
4. In terms of the changes, what have you observed about the lesson study, if anything?
5. How do you think teachers have benefited from the lesson study?
6. How did you support teachers conducting the lesson study in previous years?
7. What do you think about the mat teachers' evaluation project?
8. What does your school expect for this year for students and teachers?
9. Do you require anything from teachers who are implementing the lesson study?

Interview questions for the literacy coach

1. Overall, what was your impression of lesson study?
2. Could you elaborate the framework of the lesson study, and the role of the observers in lesson study?
3. Could you compare the biology group and what they're doing with the lesson study group?
4. Could you elaborate your concerns about lesson study (having observers that focus on specific areas and having to debrief?)
5. So are you willing to continue this lesson study for your peers?

Open-ended Survey

1. What was your suggestion for the second lesson during the first debriefing?
2. Compare and contrast the first and the second research lesson.
3. What would be possible applications (e.g. technology, instructional strategies, etc.) from the first and the second research lesson to your classroom for the near future?
4. What did you learn through the process of lesson study?
5. What, if any, was beneficial help from me as the facilitator?
6. What, if any, was your challenge in implementing the lesson study?
7. What are your concerns about your next lesson study, if you choose to do on in the near future?
8. Any other comments?

Appendix B

Preparation From the Facilitator

Initial Research Lesson Plan for the Math Group

Unit	Transformations of parent graphs	**Topic**	4.1.4. How can I model the data?		
Objectives	Students will learn how to write quadratic equations for situations using the graphing form of the parabola $y=a(x-h)^2 + k$. Specifically, students will develop an algebraic strategy for finding the value of the stretch factor, a.			**Date & Time:**	11/24/08 5-6th
Research Focus				**Teacher**	MT1

Steps of the lesson:	**Time**	**Teacher Activities**	**Students' Learning Activities**	**Things to remember**	**Goals and methods of evaluation**
Review and introduction	5 mins	• Introduce today's agenda • Review of the last class. • Introduce the today's lesson topic - Mathematical modeling with parabola • Let's read 4-46 together	• Pay attention what they are supposed to do today • Think about what they learned through the last lesson. • Take out the textbook and open p. 179 • Read 4-46 together	• Write the agenda clearly on the board • Make sure that all student have a graphing calculator • Show the question as a pdf document on the screen • Make sure that all students are looking at screen and reading 4-46	• Whole group activity
Development I (Find an equation)	15 mins	• Let's solve 4-47 as a group (or individually) • Check the group work or response students' asking	• Make groups and discuss how to solve 4-47 - a. sketch the path - b. figure out h and k - c. strategy to find a - d. domain and range - e. different equation?	• Prepare worksheet or address that they need to paper and turn it in later • Make sure that they discuss about their strategies	• Small group activity • While solving 4-47, did students actively consider discussion points and have no problem to follow further guidance?

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Things to remember	Goals and methods of evaluation
Discussion	10 mins	• Discussion 4-47 - three different equations that they come up with - discuss strategies - make sure "c"	• Answer three different equations	• Not to use vertex to find "a"	• Did students come up with three different equations with own strategies?
Development II (Further practice to find equations)	15 mins	• Let's solve 4-48 and 4-49 as a group activity • Check the group work or response students' asking	• Make groups and discuss how to solve 4-48 - Distance of 150 feet - Height of 100 feet • Make groups and discuss how to solve 4-49 - Dips 15 feet below the ground - The width is 40 feet	• Address that they need to a piece of paper and turn it in the next day	• Did students have accurate answers of 4-48? • Did students have accurate answers of 4-49?
Wrap-up/ Announcement	10 mins	• Ask what students learned • Take out the learning log and write down what you have learned today • Remind students of homework • Announce for the next lesson transforming other parent graphs	• Our group used distance and height • Our group used graph to find a vertex of parabola . • Write what they have learned today - Strategy to find equations • Write down homework • Look at the textbook		• Were students able to summarize what they have learned today?

Initial Research Lesson Plan for the Science Group

Unit	Scientific Inference	**Topic**	Inference questions		
Objectives	Students will learn how to answer inference questions for scientific reading through comparison and discussion. Specifically, students will develop an inference skill for finding the main points of the reading passage.			**Date & Time:**	4/06/ 09 5-6th
Research Focus				**Teacher**	ST1

Steps of the lesson:	**Time**	**Teacher Activities**	**Students' Learning Activities**	**Things to remember**	**Goals and methods of evaluation**
Introduction	5 mins	• Introduce the today's lesson topic - Inference question • Explain how to make a pair - Find your partner with same color sticker - Grab individual reading passage and worksheet - Read a passage and answer questions on the worksheet together • Explain how to make a group - Find your group with same number on your sticker - Have a worksheet for the group - Discuss and answer questions on the worksheet • Let's start to make a pair first	• Pay attention what they are supposed to do today • Find a partner for the pair • Grab worksheets points	• Write the agenda clearly on the board • Make sure that all students are paying attention • Make sure that all student have a worksheet and passage	• Whole group activity • Did students understand all procedures?
Development (answer inference questions)	15 mins	• Let's read a passage and find answers	• Read passage and think about answers	• Make sure that they discuss based on their strategies	• Pair activity • While reading, did students actively answers questions? • Did students have accurate answers of each question?

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Things to remember	Goals and methods of evaluation
Discussion	15 mins	• Let's make a group - Find your group with same number on your sticker - Have a worksheet for the group - Discuss and answer questions on the worksheet	• Find a group and grab the worksheet • Discuss and compare their answers	• Make sure that all groups have a worksheet	• Did students come up with different answers based on own inference skills? • Which one is their best?
Development II (Further discussion)	10 mins	• Let's discuss as a whole group	• Make groups and discuss how to answer inference questions	•	•
Wrap-up/ Announcement	5 mins	• Ask what students learned • Remind students of homework • Announce for the next lesson transforming other parent graphs	• Write what they have learned today - Strategy to find equations • Write down homework • Look at the textbook		• Were students able to summarize what they have learned today? • Did students write what they were supposed to know?

Observation Form for Math Group

Unit	Transformations of parent graphs	**Topic**	4.1.4. How can I model the data?		
Objectives	Students will learn how to write quadratic equations for situations using the graphing form of the parabola $y=a(x-h)^2 + k$. Specifically, students will develop an algebraic strategy for finding the value of the stretch factor, a.			**Date & Time:**	11/24/ 08 5-6th
Research Focus	For students to recognize and represent quadratic models 1. Could they write the equations? 2. Do they know about the names of shapes?			**Teacher**	MT1
Observation Focus	**1. Academic learning** **a. Could they write the equations?** **b. Do they know about the names of shapes?** **2. Motivation and engagement** **c. Some time take so long – how much time did students spend on actual lesson?** **3. Instructional features, information requested by instructor** **d. What kinds of questions did student ask?** e. **Make assumption – before read problems**				

Steps of the lesson:	**Time**	**Teacher Activities**	**Students' Learning Activities**	**Observation**
Review and introduction	10 mins	• Introduce today's agenda • Review of the last class. - Show vertex form of parabola ($y=a(x-h)^2 + k$) - Discuss what the Parameters represent - Variables – x, y • Introduce the today's lesson topic - Mathematical modeling with parabola • Let's read 4-46 together • Emphasize discussion	• Pay attention what they are supposed to do today • Think about what they learned through the last lesson. - Identify the parameters - graphing form or vertex form of parabola $y=a(x-h)^2 + k$ • Take out the textbook and open p. 179 • Read 4-46 together • Listen carefully to discussion points	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
		points - How can we make a graph fit this situation - What information do we need in order to find an equation? - How can we be sure that our equation fits the situation?		
Development I (Find an equation)	15 Mins	• Let's solve 4-47 as a group (or individually) • Check the group work or response students' asking	• Make groups and discuss how to solve 4-47 - a. sketch the path - b. figure out *h* and *k* - c. strategy to find a - d. domain and range - e. different equation?	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
Discussion	10 mins	• Discussion 4-47 - three different equations that they come up with - discuss strategies - make sure "c"	• Answer three different equations • Discuss their own strategies	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
Development II (Further practice to find equations)	10 Mins	• Let's solve 4-48 and 4-49 as a group activity • Check the group work or response students' asking	• Make groups and discuss how to solve 4-48 -Distance of 150 feet -Height of 100 feet • Make groups and discuss how to solve 4-49 -Dips 15 feet below the ground -The width is 40 feet	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
Wrap-up/ Announcement	10 mins	• Ask what students learned -How did you find equations from different situation? -What were some difficulties to find equations? • Take out the learning log and write down what you have learned today • Remind students of homework • Announce for the next lesson transforming other parent graphs	• Our group used distance and height • Our group used graph to find a vertex of parabola • I planed to find it with calculator, but I am not good at using it. • Write what they have learned today - Strategy to find equations • Write down homework • Look at the textbook	

Observation Form for Science Group

Unit	Scientific Inference based on reading science topics	**Topic**	Reading science passage and group inference questions		
Objectives	Students will read information about science topics in a way that they can understand them and pull information out that is important to them. Students will understand that reading just the words only gives them a small amount of information from reading a passage.			**Date & Time:**	4/06/09 5-6th
Research Focus	In order to improve students' ability on the reading science passage for standardized tests, how are teachers able to encourage students to get involved in reading science topics with the various skills needed to do well on the standardized tests?			**Teacher**	Frank
Observation Focus					

Steps of the lesson:	**Time**	**Teacher Activities**	**Students' Learning Activities**	**Observation**
Introduction	5 mins	• Introduce the today's lesson topic - Inference question • Explain pair work - Find your partner - Have reading passages and a worksheet - Read passages with your partner, taking turns reading - Once you have finished, discuss and answer the questions on a worksheet • Let's start to make a pair first	• Pay attention what they are supposed to do today • Find a partner for the pair • Have passages and a worksheet	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
Development I (answer inference questions)	15 Mins	• Let's read passages with your partner and discuss and answer the questions based on what you read • Both of you will write the answer on your sheet • If you do not agree with you r partner, then you both should write both answers	• Read passage and discuss and think about answers with their partners.	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
Discussion	15 mins	• Let's make a whole group • Let's answer questions together • What does Uncle Tungsten mean when he refers to copper, silver, and gold as native, pure metals? • Who is the "she" that Uncle Tungsten in talking about when he says "she offers the platinum metals, too"? • In the 2nd paragraph, what does the phrase "destitute of metallic splendor" imply? • What does Uncle Tungsten mean at the end of the 2nd paragraph when he says, "There can	• Come back to the whole group • Discuss and compare their answers as a whole group • These metals are found naturally isolated and not combined with other substances like oxides. • Mother Nature • It implies that the oxides or Earths were not metals because they did not have properties of metals • He meant that it is possible to develop a process for doing something without actually	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
		be a deep practical knowledge long before theory?" • According to the passage, what did cavemen have to do with the discovery of new metals in the eighteenth century? • At the end of the passage, the author says that all of the carbon was gone after the crucible was taken from the furnace. Where did the carbon go?	knowing how it works, For example, smelting was used long before science understood how the process worked chemically. • When they lined cooking fires with rocks, the rocks were heated along with the carbon from the fire and in the process discovered the process we know as smelting which we used to retrieve metals from their ones. • The carbon combined chemically with the oxygen from the tungsten oxide	

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Observation
Wrap-up/ Announcement	5 mins	• Ask what students learned • Announce for the next lesson	• Find main points of reading passages based on the inference skill	

The Actual Schedule for Math Group Lesson Study

Time	Participants	To do	Prep
First planning time (Nov. 4th)			
1:30 – 2:00 PM	MT1 MT2 MT3 F3	Lesson study planning time Set the schedule for lesson study Think about research theme	Digital Recorder Observation sheet Lesson study materials (math department meeting)
Second planning time (Nov. 12th)			
1:00 – 3:00 PM (9-11th hour)	MT1 MT2 MT3 F3	Planning time Rethink about research theme based on the goals of math department Complete research lesson plan	Digital Recorder Initial research lesson plan Observation protocol MT1 and MT2 need subs
First delivering lesson by MT1 (Nov. 24th)			
11:00 – 12:00 AM	MT1 MT2 MT3 F3	Algebra II class observation	MT1's classroom MT2 needs sub
12:00 – 1:00 PM	MT1 MT2 F3	Debriefing Modifying the second version of the research lesson	
Second delivering lesson by MT2 (Nov. 25th)			
2:00 – 3:00 AM	MT1 MT2 MT3 F3	Algebra II class observation	MT2's classroom MT1 needs sub
3:00 – 4:00 PM	MT1 MT2 MT3 F3	Debriefing	

The Actual Schedule for Science Group Lesson Study

Time	Participants	To do	Prep
First planning time (Jan. 9th)			
1:30 – 2:00 PM	ST1 ST2 ST3 F3	Lesson study planning time Think about research theme	Digital Recorder Lesson study materials
Second planning time (Feb. 25th)			
2:00 – 2:10 PM	ST1 ST2 F3	Lesson study planning time Think about a tentative schedule for lesson study	Digital Recorder
Third planning time (Mar. 25th)			
1:20 – 2:10 PM	ST1 ST2 ST3 L1 F3	Lesson study planning time Rethink about research theme based on the goals of math department Set the tentative schedule for lesson study	Digital Recorder Lesson study materials ST3 needed sub
Fourth planning time (Mar. 31st)			
1:00 – 2:00 PM	ST1 ST2 ST3 L1 F3	Planning time Organize the content of the unit of science reading Initiate a research lesson plan	Digital Recorder Initial research lesson plan Observation protocol ST3 needed sub
First delivering lesson by ST1 (Apr. 6th)			
11:00 – 12:00 PM	ST1 ST2 ST3 L1 F3	Basic Chemistry class observation	ST1's classroom ST3 needs sub
1:00 – 2:00 PM	ST1 ST2 ST3 L1 F3	Debriefing Modifying the second version of the research lesson	Science lab ST3 needs sub
Second delivering lesson by ST2 (Apr. 7th)			
12:00 – 1:00 PM	ST1 ST2 ST3 L1 F3	Chemistry class observation	ST2's classroom ST3 needs sub
1:00 – 2:00 PM	ST1 ST2 ST3 L1 F3	Debriefing	Science lab ST3 needs sub

Initial Evaluation Project Report for Math Group

Research lesson for lesson study

1. Unit: Chapter 4. Transformations of parents graphs
2. Unit Objectives

   You will have the opportunity to:

   - Transform a graph by stretching or compressing it, shifting it left or right, or flipping it.
   - Write a general equation for a family functions
   - Model physical situations with quadratic functions.
   - Write equations in graphing form
3. Overarching goals for teaching

   As following mathematics department goals of this year, teachers need to pay attention to:

   1) Continue discussion on cooperative learning
   2) Continue communication between teachers of like courses
   3) Implementing and support of CPM curriculum in Algebra 2
   4) Implementing TI-84 calculator skills in Algebra 2
4. Actual Situation of the Students

Students have not been good at cooperative learning for discovering and engaging roles to be active participants, although they are getting better day by day. They are comfortable to use a graphing calculator in classroom, however they are still struggled to switch the window if the function is not in the window.

Some of students are lack of fundamental skills that they need. They understand the new materials and the concepts that they are supposed to learn, but they just do not have the skills to be able to manipulate equations and stacks. More specifically, they could understand linear and exponential situation, but they can't do quadratics or any other family of graphs (other linear and exponential situations).

5. Learning objectivities and activities of each lesson

Small group activities are major parts of the CPM curriculum

Lesson	Lesson title	Learning objective – Students will:	Learning activity	Methods; points to notice
4.1.1 (omitted)	Modeling non-linear data	Collect non-liner data, fit an equation to their data, and use their equation to make predictions	How can an equation help you predict? *What will the graph look like? *Should you connect the data points? *How can you find an equation that first the data? - the shrinking targets lab	Curriculum materials: scales, cardboard, and compasses.
4.1.2	Parabola investigation	Connect transformations of parabolas with their equations in graphing form	How can you shift a parabola? *What happens to a parabola's graph when you change the numbers in the equation?	Curriculum materials: Graph paper, graphing calculator Student Activities: Groups
4.1.3	Graphing a parabola without a table	Graph quadratic equations without making tables. Students will rewrite quadratic equations from standard form into graphing form.	How can you graph it quickly? - graphing and standard form of parabolas	Curriculum materials: Dynamic tool Learning process: Compare non-using calculator and using it
4.1.4 **(the research lesson)**	Mathematical modeling with parabola	Learn how to write quadratic equations for situations using the graphing form of the parabola $y=a(x-h)^2 + k$. Specifically, students will develop an algebraic strategy for finding the value of the stretch factor, a.	How can you model the data? *How can you make a graph fit this situation? *What information do you need in order to find an equation? *How can you be sure that our equation fits the situation? - jumping jackrabbits	Curriculum materials: Paper for sketch Graph paper Support/ Evaluation: Learning log
4.2.1	Transforming other parent graphs	Transform the graph $y= b^x$, $y=1/x$, $y=x$, and $y=x^3$	How can you transform any graph? *How can you move a parabola? *How can you use our ideas about moving parabolas to move other functions? *What changes can you make to the equation?	Curriculum materials: Poster paper, markers Student Activities: Groups
4.2.2	Describing (h, k) for each family of functions	Identify the point (h, k) for parabolas, hyperbolas, cubics, and square root graphs, and relate the Point-Slope form of a line to (h, k). They will consolidate their understanding of parent graphs and general equations in the Parent Graph Tool Kit.	What is the significance of (h, k)? - the parent graph tool kit - point-slope equations for lines	Curriculum materials: The Parent graph tool kit Student Activities: Groups Support/ Evaluation: Learning log

4.2.3	Transforming the absolute value parent graph	Use what they know about transformations to write a general equation for a family of functions based on an absolute value parent graph.	Can you transform a new function? - Shifting graphs to find the general equation for a new parent function	<u>Student Activities:</u> Groups <u>Support/ Evaluation:</u> Learning log
4.2.4	Transforming non-functions	Use what they know about transforming parabolas to make conjectures about transforming relations, specifically parabolas in the form $x=y^2$ (which will be called "sleeping parabolas") and circles. They will define the meaning of a non-function.	How can you transform relations? *How can you change the equation so that the graph moves horizontally? Vertically? *How can the graph be stretched? Flipped? - relations and functions	<u>Curriculum materials:</u> Blank paper <u>Student Activities:</u> Personal poster
4.3.1	Completing the square	Learn how to convert a parabola into graphing form by completing the square.	How can you write it in graphing form?	<u>Curriculum materials:</u> Algebra tiles
4.3.2	More completing the square	Extend the idea of completing the square to change circles written in standard form into graphing form.	How can I find the center of a circle? - general equations for families	<u>Curriculum materials:</u> Algebra tiles

6. Research lesson (4.1.4)
    a. The aims of this lesson - Learn how to write quadratic equations for situations using the graphing form of the parabola $y=a(x-h)^2 + k$. Specifically, students will develop an algebraic strategy for finding the value of the stretch factor, *a*. (Understand how to model real life situations with parabolas.)
    b. Research focus - For students to recognize and represent quadratic models
        1) Academic learning
            i. Could they write the equations?
            ii. Do they know about the names of shapes?
        2) Motivation and engagement
            i. Some time take so long – how much time did students spend on actual lesson?
        3) Instructional features, information requested by instructor
            ii. What kinds of questions did student ask?
            iii. Make assumption – before read problems

Appendix C

Activities of Lesson Study

The Actual Research Lesson Plan for the First Delivering for Math Group

Unit	Transformations of parent graphs	**Topic**	4.1.4. How can I model the data?		
Objectives	Students will learn how to write quadratic equations for situations using the graphing form of the parabola $y=a(x-h)^2+k$. Specifically, students will develop an algebraic strategy for finding the value of the stretch factor, *a*.			**Date & Time:**	11/24/08 5-6th
Research Focus	For students to recognize and represent quadratic models 1. Could they write the equations? 2. Do they know about the names of shapes?			**Teacher**	MT1

Steps of the lesson:	**Time**	**Teacher Activities**	**Students' Learning Activities**	**Things to remember**	**Goals and methods of evaluation**
Review and introduction	10 mins	• Introduce today's agenda • Review of the last class. - Show vertex form of parabola ($y=a(x-h)^2+k$) - Discuss what the Parameters represent - Variables – *x, y* • Introduce the today's lesson topic - Mathematical modeling with parabola • Let's read 4-46 together • Emphasize discussion points - How can we make a graph fit this situation - What information do we need in order to find an equation? - How can we be sure that our equation fits the situation?	• Pay attention what they are supposed to do today • Think about what they learned through the last lesson. - Identify the parameters - graphing form or vertex form of parabola $y=a(x-h)^2+k$ • Take out the textbook and open p. 179 • Read 4-46 together • Listen carefully to discussion points	• Write the agenda clearly on the board • Make sure that all student have a graphing calculator • Show the question as a pdf document on the screen • Make sure that all students are looking at screen and reading 4-46	• Whole group activity • Did students understand all discussion points?
Development I (Find an equation)	15 mins	• Let's solve 4-47 as a group (or individually) • Check the group work or response students' asking	• Make groups and discuss how to solve 4-47 - a. sketch the path - b. figure out *h* and *k* - c. strategy to find a - d. domain and range - e. different equation?	• Prepare worksheet or address that they need to paper and turn it in later • Make sure that they discuss about their strategies	• Small group activity • While solving 4-47, did students actively consider discussion points and have no problem to follow further guidance? • Did students have accurate answers of each question? • Did students manipulate calculators in the right way?

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Things to remember	Goals and methods of evaluation
Discussion	10 mins	• Discussion 4-47 - three different equations that they come up with - discuss strategies - make sure "c"	• Answer three different equations • Discuss their own strategies	• Not to use vertex to find "a" • Different locations for the axis • Each group might have different equations	• Did students come up with three different equations with own strategies? • Which one is their best?
Development II (Further practice to find equations)	10 mins	• Let's solve 4-48 and 4-49 as a group activity • Check the group work or response students' asking	• Make groups and discuss how to solve 4-48 - Distance of 150 feet - Height of 100 feet • Make groups and discuss how to solve 4-49 - Dips 15 feet below the ground - The width is 40 feet	• Address that they need to a piece of paper and turn it in the next day	• Each student can do individually within a group • Did students have accurate answers of 4-48? • Did students have accurate answers of 4-49?
Wrap-up/ Announcement	10 mins	• Ask what students learned - How did you find equations from different situation? - What were some difficulties to find equations? • Take out the learning log and write down what you have learned today • Remind students of homework • Announce for the next lesson transforming other parent graphs	• Our group used distance and height • Our group used graph to find a vertex of parabola • I planed to find it with calculator, but I am not good at using it. • Write what they have learned today - Strategy to find equations • Write down homework • Look at the textbook	• Put up the p. 177 on the board • Look at p. 177 • HW: 51 - 58	• Were students able to summarize what they have learned today? • Did students write what they were supposed to know?

The Actual Research Lesson Plan for the First Delivering for Science Group

Unit	Scientific Inference based on reading science topics	**Topic**	Reading science passage and group inference questions		
Objectives	Students will read information about science topics in a way that they can understand them and pull information out that is important to them. Students will understand that reading just the words only gives them a small amount of information from reading a passage.			**Date & Time:**	4/06/09 5-6th
Research Focus	In order to improve students' ability on the reading science passage for standardized tests, how are teachers able to encourage students to get involved in reading science topics with the various skills needed to do well on the standardized tests?			**Teacher**	ST1

Steps of the lesson:	**Time**	**Teacher Activities**	**Students' Learning Activities**	**Things to remember**	**Goals and methods of evaluation**
Introduction	5 mins	• Introduce the today's lesson topic • Inference question • Explain pair work • Find your partner • Have reading passages and a worksheet • Read passages with your partner, taking turns reading • Once you have finished, discuss and answer the questions on a worksheet • Let's start to make a pair first	• Pay attention what they are supposed to do today • Find a partner for the pair	• Write the agenda clearly on the board • Make sure that all students are paying attention • Make sure that all student have a worksheet and passages	• Whole group activity • Did students understand all procedures?
Development I (Answer inference questions)	15 mins	• Let's read passages with your partner and discuss and answer the questions based on what you read • Both of you will write the answer on your sheet • If you do not agree with you r partner, then you both should write both answers	• Read passage and discuss and think about answers with their partners.	• Make sure that students discuss based on their reading • Encourage them to read passages carefully	• Pair activity • While reading, did students actively answers questions? • Did students have appropriate answers of each question?

Steps of the lesson:	Time	Teacher Activities	Students' Learning Activities	Things to remember	Goals and methods of evaluation
Discussion	15 mins	• Let's make a whole group • Let's answer questions together • What does Uncle Tungsten mean when he refers to copper, silver, and gold as native, pure metals? • Who is the "she" that Uncle Tungsten in talking about when he says "she offers the platinum metals, too"? • In the 2nd paragraph, what does the phrase "destitute of metallic splendor" imply? • What does Uncle Tungsten mean at the end of the 2nd paragraph when he says, "There can be a deep practical knowledge long before theory?" • According to the passage, what did cavemen have to do with the discovery of new metals in the eighteenth century? • At the end of the passage, the author says that all of the carbon was gone after the crucible was taken from the furnace. Where did the carbon go?	• Come back to the whole group • Discuss and compare their answers as a whole group • These metals are found naturally isolated and not combined with other substances like oxides. • Mother Nature • It implies that the oxides or Earths were not metals because they did not have properties of metals • He meant that it is possible to develop a process for doing something without actually knowing how it works, For example, smelting was used long before science understood how the process worked chemically. • When they lined cooking fires with rocks, the rocks were heated along with the carbon from the fire and in the process discovered the process we know as smelting which we used to retrieve metals from their ones. • The carbon combined chemically with the oxygen from the tungsten oxide	• Make sure that students complete their worksheets	• Whole group activity • Did students come up with proper answers based on the inference skill?
Wrap-up/ Announcement	5 mins	• Ask what students learned • Announce for the next lesson	• Find main points of reading passages based on the inference skill		• Were students able to summarize what they have learned today?

Lesson Study Reflection Paper (MT1)

For my Track II evaluation, I chose to do a lesson study with MT2 as the other teacher and the facilitator (the researcher of this study). MT3 also participated in the planning and observation of the lesson. MT2 and I chose to use Algebra II as our class to do the lesson study. We are currently using the College Preparatory Math Series—Algebra II Connections as our text. This is a new text that we are implementing this year. One of the reasons that we chose this class is so that we would have the opportunity to look more closely at how the new curriculum is working for these students and how their algebra and geometry curriculum has played a role in their success and/or failure to this point in algebra II.

There were several issues that we discussed during our planning meetings concerning the students and their backgrounds. These group of students from our school have been the first group through the new algebra I curriculum 2 years ago (Discovering Algebra), the first group through the new geometry curriculum (CPM Geometry Connections) last year and are now the first group going through the new algebra II curriculum (CPM Algebra II connections). We also pointed out that not only are they the first group of students through the curriculum, but for most of the teachers it was also their first time through the new curriculum. We know that there can be a dip with any new curriculum so we are trying to decide which issues are related to the natural dip in the implementation process and what issues may be related to the curriculum or the instruction by different teachers.

Many of my reflections are based not just on the lesson itself, but about the ideas that were shared when we were discussing the class, the curriculum and the lesson that we were teaching.

In the planning process MT2 and I shared the concern that some students are very good at working cooperatively with other students, but certainly not all students. The goal of the curriculum is to let the students work their way through the material with guidance from the teacher. It does take some amount of struggling with the material and making mistakes to get to the discovery process. The balancing act of the teacher needs to be to encourage the students to try to work out the problems on their own without stepping in too soon and just telling them how to do the problem. At the same time, the teacher needs to try to prevent the students from getting too frustrated because they feel they have no help at all and as a result they shut down. MT2 and I discussed how it is easy to fall into the habit of just telling the students how to do the problem instead of giving them the time to work through it. It seems that the more you tell the students how to do the problems, then the more they expect you to tell them how to do the problems and they become more resistant to the cooperative learning and discovery process. I think the teacher will often tell the students what to do because it seems to "save time" because it takes much less time to just tell them how to do the problems than to let them discover the problems on their own.

The second main topic that we discussed and thought about was the basic skills that the students came into the class with. When we were discussing the lesson, I had shared with the team that it seems my students had a lack of basic algebra skills that seemed to hinder them in completing the lessons successfully and in a timely manner. It seemed that they were able to understand the new concepts that we were working on for algebra II but weren't able to finish off the problems because of basic algebra errors or major misconceptions in how to solve an equation. I have had discussions with other algebra II teachers this year and came into the lesson study feeling like my classes were the only ones that were struggling with their algebra I skills.

I was the first one to teach the lesson. Since I have two algebra II classes, I actually taught the lesson back to back, but it was only observed by the team during the second class. It went really well the first time and I was pleasantly surprised to see the teams work cooperatively together and struggle through the process a little bit to figure out a way for them to solve for a, but they all persevered and were able to complete the first problem. All of the teams in that class were able to complete that teamwork assignment that we had established for the day.

When the team came to observe the lesson the second time I taught it, I had almost the same results. It did seem that two groups in particular during the lesson study seemed to struggle with some of the basic algebra skills that I had shared was a concern of mine prior to the lesson. I was happy that the lesson study team members were able to observe how the lack of skills in some slowed down their group tremendously. I think it never really occurred to me that the pace of the group had a lot to do with the fact that time had to be taken for me to go over basic algebra (which often took more than just a reminder) with some individuals. I feel that I tend to focus on the students that can't seem to solve equations that I think are within their abilities. The team did point out that the majority of the students in the class were successful with the lesson and were able to complete the lesson.

The next day MT2 taught the lesson in her algebra II class. My job was to observe the academic learning in the classroom. As I walked around I noticed that many of the students in her class had similar struggles with the algebra skills also. I think for me to see that my students weren't the only students struggling with this was an eye opener for me. It definitely has changed my perspective on my classes and how far many of my students have come since the beginning of the year because I have allowed them to struggle through their errors and now they

seem to work through them more quickly. All of the groups in my classes but one were able to complete the 2 problems that came after the initial discovery problem!

Overall, the lesson study was a great experience. I was a little apprehensive to begin with but having the facilitator help to facilitate the process and also to have MT3 sit in with us in the initial planning stages was very helpful. The discussion of the main issues that I had been dealing with—working cooperatively, completing the teamwork (how much time is wasted) and the lack of basic algebra skills was very beneficial to me. I think on the final day, we indirectly came to the conclusion that the amount of time it takes them to complete the teamwork is related to the lack of basic algebra skills. Those that struggle with solving or manipulating equations tend to be the ones who don't finish on time. I also realized that I do need to focus on the positives in my class—the fact that 80 to 90% of the students are completing the assigned tasks. We also came to the conclusion that if we emphasize how to solve equations whenever it comes up (doing the opposite), then maybe they will retain the concept better and be able to be more successful in the future.