ABSTRACT

Lesson Study: The Effects On Teachers and Students
In Urban Middle Schools

Rachelle D. Meyer

Mentor: Trena L. Wilkerson, Ph.D.

This multiple case study examined the effects lesson study had on middle school mathematics teachers and students in a large urban school district. The participants for this study consisted of 13 middle school mathematics teachers who formed three lesson study groups. The research questions were: (1) What effects does lesson study have on middle school mathematics teachers? (2) What effects does lesson study have on middle school students? (3) Does the participation in lesson study as a form of professional development serve as a catalyst for the growth and continuation of lesson study within the middle school mathematics community?

This qualitative research used nine measures to gather data which consisted of the following: two baseline surveys; transcripts from planning and reflection sessions; observation notes; lesson plans; teacher logs; students' work; a district nine-week assessment; and electronic discussions. Analysis of the data revealed lesson study did impact teachers' instructional strategies in the areas of self-reflection, incorporating problem-solving activities, and encouraging cooperative learning. Evidence also indicated that teachers' content knowledge did improve for two of the three case studies

as a result of teacher collaboration. The impact lesson study had on students' understanding and achievement was limited. Students' achievement in mathematics for two participating middle schools appeared to improve; however, caution must be exercised when attempting to generalize the impact lesson study had on students. There was, however, evidence to support that lesson study had a positive impact on students' engagement in mathematics. In addition, over 50 percent of the participating teachers elected to engage in a second lesson study with some recruiting additional teachers from their campuses.

Lesson Study: The Effects On Teachers and Students In Urban Middle Schools

by

Rachelle D. Meyer, B.A., M.Ed.

A Dissertation

Approved by the Department of Curriculum and Instruction

Tony L. Talbert, Ed.D., Interim Chairperson

Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of
Doctor of Education

Approved by the Dissertation Committee

Trena L. Wilkerson, Ph.D., Chairperson

Betty J. Conaway, Ph.D.

Larry J. Browning, Ed.D.

Douglas W. Rogers, Ed.D.

Baxter Johns, Ph.D.

Accepted by the Graduate School
December 2005

J. Larry Lyon, Ph.D., Dean

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGMENTS

This dissertation is the reward for a very long journey that began almost seven years ago. While teaching sixth grade mathematics, I traveled four hours once a week in order to begin my doctoral studies. After three years of commuting, I moved home in order to accomplish my goal of earning a doctorate. It is with great pride and gratitude that I acknowledge those people who helped me accomplish my dream.

First, I must thank Dr. Trena Wilkerson, chair of my dissertation committee, who has been a mentor, friend, and inspiration throughout the program. Dr. Wilkerson not only taught me how to be a better teacher, but provided me with numerous opportunities to grow as a professional. I am indebted to her for her support, high expectations, kindness, and genuine care.

I would also like to thank Dr. Betty Conaway, Dr. Doug Rogers, Dr. Larry Browning, and Dr. Baxter Johns for serving on my dissertation committee. Dr. Conaway, a very dear friend, reassured me during trying times and was always willing to talk. Her support and encouragement throughout this doctoral program will always be remembered. Dr. Rogers, my dear friend, supported me throughout my years at Baylor. His faith in my abilities and expertise provided me with a source of strength that I am forever grateful. Dr. Browning challenged, supported, and encouraged me throughout the doctoral program in which I am greatly appreciative. Dr. Johns provided input and encouragement. I am grateful for the efforts, dedication, and time spent on my behalf.

There is a group of individuals who often made me laugh when I was ready to cry. I would like to thank my very dear friends. To my San Marcos buddies: Rebecca

Pavlat, Pam Roberts, Kay Posey, and Hulda Kercheville, thank you for your belief in me and your continuous support. I love you guys! To Barbara Purdum-Cassidy, our friendship began the first graduate class we had together and continued to grow throughout the years. Thank you for being such a wonderful friend and for your continuous support.

Finally, I would like to thank my precious family for the sacrifices they endured during my journey to receive a doctorate. To my mother, there are no words to describe my appreciation and gratitude for the support you gave throughout this process. Thank you for helping with the house and animals when I did not have a minute to spare; however, thank you most of all for when I doubted myself, you simply smiled and said that if anyone could do it, I could. Your constant belief in me is very humbling. I love you with all my heart.

To Pop and Meme, my dear grandparents, your support is greatly appreciated. Pop, I would like to thank you for taking care of the house and yard. Meme, I would also like to thank you for cooking the wonderful "goodies" when I did not seem to have time to boil water. Most of all, thank you for having faith and pride in me. I noticed that when we talked about my doctorate, your eyes would tear-up with pride and joy. I am so very proud to have you for grandparents.

To Brent, Meredith, Blake, and Kendra, thank you for your understanding and support. Brent, my dear brother, I do not think you know it, but you were the one who actually motivated me to get the job done. Numerous times you casually asked me the simple question, "Are you going to get it finished?" I finally got tired of saying, "I hope so," and decided the next time you asked, the answer was going to be "yes." Brent, I would like to thank you for the casual question and for helping with the yard when you had a hundred other things to do. To Meredith, my precious sister-in-law, I could not have finished this dissertation without you. Thank you for the numerous hours you spent typing and formatting my dissertation when you could have been home with your wonderful children. Blake and Kendra, my dear nephew and niece, thank you for understanding and being so sweet about not spending the night because I had to write. Guess what, it is time to start spending the night again.

I have dedicated this work to my mother and to the memory of my father. They fostered in me the value of an education and a love for learning. Mother, thank you for your love and faith in me, and even though Dad is no longer with us, I have no doubt that he is smiling from above.

To my parents,
with all my love and gratitude

CHAPTER ONE

Introduction

In America, a visitor walks into a mathematics classroom and expects to see the following "script" for a mathematics lesson: teacher instructs class in skill or concept, teacher solves example problems with students, students practice while teacher assists individual students, and teacher assigns practice problems for homework. Meanwhile, on the other side of the world in Japan, a visitor walks into a mathematics classroom and expects to see the following "script" for a mathematics lesson: teacher presents rich problem, students struggle with problem, students share ideas/solutions, class discusses strategies used, teacher concludes (National Research Council, 2001a; California State University, 1997). Not only are the "scripts" different, but the audiences have distinct characteristics as well. The American classroom consists of one teacher and approximately twenty-five students, while the Japanese classroom consists of one teacher, approximately forty students, and several other teachers observing the lesson (Lewis & Tsuchida, 1998). While the American teacher works in isolation, the Japanese teacher works in a collaborative environment (Lewis, 2000a).

According to Lewis (2000a), Japanese instructional improvement rests on a majority of the time consisting of classroom observations, discussions among teachers, and collaborative work to refine classroom lessons. Furthermore, limited time is given to finding or writing curriculum that aligns with standards. On the other hand, American instructional improvement rests on a majority of time consisting of finding or writing curriculum in order to align it with standards and then individually planning lessons with very limited opportunities to watch and discuss lessons with colleagues (Lewis, 2000a; Stigler & Hiebert, 1999). One reason for this major difference in collaboration time among teachers is that the primary form of professional development in Japan is established through observation and collaboration among teachers, while professional development in the United States takes on a much different format (Lewis, 2000a; Yoshida, 1999; Stigler & Hiebert, 1999).

In the United States, professional development is used to help teachers with pedagogical decisions and strategies for effective instruction as well as helping teachers understand the mathematics they teach. The most commonly used forms of professional development include short sessions at meetings, one-to-two-day school-based workshops on specific topics, or two-to-three-week grant supported workshops in the summer (National Research Council, 2002a; Smith, 2001; Guskey, 2000).

Similar to educators in the United States, Japanese educators use professional development to enhance their practice, to learn more mathematics and pedagogical strategies, and improve their instructional approaches (National Research Council, 2002a); however, the most commonly used form of professional development is observation and collaboration of teachers through lesson study (Yoshida, 1999; Stigler & Hiebert, 1999). Lesson study is an in-school teacher education strategy consisting of pre-collaborative work among teachers, lesson observations, and post-collaborative work (Lewis, 2000a; Stigler & Hiebert, 1999; Yoshida, 1999).

In the United States, a national mathematics curriculum is non-existent; however, the National Council of Teachers of Mathematics (NCTM) has issued several documents outlining standards in mathematics with the most recent being the publication of *Principles and Standards for School Mathematics* in 2000. These standards are supported by the National Science Foundation and the United States Department of Education and provide guidelines for teachers in mathematics (National Research Council, 2002a; National Council of Teachers of Mathematics, 2000). Such standard documents published by NCTM focus on mathematics as reasoning. Students should be recognized as mathematical thinkers who are encouraged to “use a variety of methods for representing and solving problems and then present their work to their classmates for further analysis” (National Research Council, 2002a, p. 23) while making connections among mathematical facts, procedures, and concepts (National Council of Teachers of Mathematics, 2000).

The “script” describing the American mathematics classroom previously mentioned does not appear to reflect the recommendations of the NCTM; yet, the “script” for the Japanese classroom appears to be much more supportive of the NCTM standards. Over the last two decades, NCTM has made strong efforts to improve the teaching of mathematics (National Council of Teachers of Mathematics, 1989, 1991, 2000) and according to the research of Stigler and Hiebert (1999), a large percentage of mathematics teachers are aware of the reforms and claim to have implemented them into their classrooms. The 1999 video analysis of eighth-grade mathematics lessons in the United States, studied after the Third International Mathematics and Science Study (TIMSS), revealed that 69 percent of the problems focused on mathematical procedures, 13 percent on stating concepts, and only 17 percent on making connections. Meanwhile, when viewing eighth-grade mathematics lessons in Japan, analysts noted 41 percent of the problems focused on mathematical procedures, 5 percent on stating concepts, and 54 percent on making connections (U.S. Department of Education, 2003). Even though American mathematics teachers have the best of intentions to adopt the latest research and reform movements into their classrooms, teachers often misinterpret reform and merely change surface features (Knapp & Sowder, 2004; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Stigler & Hiebert, 1999).

Teachers are the key to changing the way students learn mathematics (Dana & Yendol-Silva, 2003; Darling-Hammond, 1998), yet the suggested reform strategies for learning mathematics do not appear to transfer into the classroom (U.S. Department of Education, 2003). Therefore, can the Japanese professional development approach of lesson study be a means to improving American teachers' instructional strategies and students' understanding in mathematics?

International Mathematics Comparisons

Today children are growing up in a society permeated by mathematics (National Research Council, 2001a; Moses & Cobb, 2001; National Council of Teachers of Mathematics, 2000; Papert, 1993). Technologies used in homes, businesses, and schools are built on mathematical knowledge, and many careers demand high levels of mathematics (National Research Council, 2001a). It serves as a universal language and an integral part of modern life such that anyone who wishes to be a fully participating member of society must be knowledgeable in basic mathematics (National Research Council, 2001a; Stevenson & Stigler, 1992). Due to the importance of mathematics, more national and international studies have been conducted in mathematics than any other field of study (Ma, 1999; Stigler & Hiebert, 1999; Robitaille & Travers, 1992).

Many articles, papers, and books have focused on the results of international comparisons in mathematics. The popular media, as well as government agencies, have reflected this interest in international comparative studies (Stigler & Hiebert, 1997; Stevenson & Stigler, 1992). For example, in 1967 the First International Mathematics

Study consisting of 12 countries resulted in American eighth graders finishing next to last (Atweh, Clarkson, & Nebres, 2003; Battista, 1999; Robitaille & Travers, 1992). In 1981, the Second International Mathematics Study consisting of 21 countries resulted in America's eighth graders finishing at or below the median for all participating nations (Atweh, Clarkson, & Nebres, 2003; National Commission on Excellence in Education, 1983). In1995, the Third International Mathematics and Science Study (TIMSS) consisting of 41 countries resulted in America's eighth graders finishing slightly below the international average in mathematics (Atweh, Clarkson, & Nebres, 2003; National Research Council, 2001a; U.S. Department of Education, 1996). What is particularly revealing regarding TIMSS is that this study focused on curricula and instructional strategies as well as students' mathematical abilities. Consequently, the report provides suggestions about what needs to be improved and how to go about making these improvements. As a result of the suggested improvements from the TIMSS, 38 countries, in 1999, agreed to assess their eighth graders in an international context in a repeat study, which became known as TIMSS-R. America's eighth graders were reported as showing no improvement from the 1995 TIMSS (U.S. Department of Education, 2003; Germain-McCarthy, 2001). Moreover, these international comparisons suggest that by eighth grade, the performance of American students in mathematics is well below that of most Asian students, particularly Japanese, and students in many European countries (U.S. Department of Education, 2003; National Research Council, 2001a; Stevenson & Stigler, 1992). Consequently, national organizations such as the NCTM and the National Science Board have called for reform in teaching and learning mathematics (Loucks-Horsley et al., 2003; Moyer & Packenham, 2001; National Council of Teachers of Mathematics, 2000). The call is for teachers who can support student learning by creating classroom environments that support communication, inquiry, and investigation (Knapp & Sowder, 2004; Smith, 2001).

Approaches to Teaching Mathematics

For more than a century, observers have been viewing classrooms and emerging with descriptions of how U.S. teachers teach. Conclusions indicate the way in which the teachers teach their particular subject matter has changed very little over the years (National Research Council, 2001a). "The vast majority of whom were taught and learned to teach under a paradigm of instruction and learning in which memorization, repetition, speed, and correct answers were of paramount importance" (Smith, 2001, p. 3). Even with today's high standards, exemplary textbooks, and powerful assessments, the key for mathematics learning is the interactions that take place in the classrooms and overall, teachers' acknowledge the different approaches to teaching and learning mathematics (National Research Council, 2001a). These instructional approaches in teaching mathematics range from traditional to constructivist.

Traditional

In 1828, the Yale faculty, essentially as an impassioned defense of traditional education, composed a report recognizing two main functions of education: strengthening the mind and filling the mind with knowledge and skills. The document referred to the mind as a muscle and consequently, this belief provided the backdrop for classrooms that require monotonous drill and mindless verbatim recitation (as cited in Kliebard, 1995).

Even now a traditional mathematics classroom can be described as a teacher who teaches strictly by the adopted school curriculum and relies heavily on textbooks and worksheets to fill the mind with knowledge and skills (Van de Walle, 2004; National Research Council, 2001a; Ben-Peretz, 1990; Goodlad, 1984). With this approach, teachers generally behave in a didactic manner, providing information to students. In other words, the learning of mathematics is a series of memorizing facts and procedures (National Research Council, 2001a; Ohanian, 1999). For example, typical mathematics classrooms, in 1979, seemed to have followed a routine. First, answers were given for the previous day's homework. Next, a brief explanation was given of the new concept, and problems were assigned for the next day. The remainder of class was devoted to working on the assignment (Stigler & Hiebert, 1999; Fay, 1979). Even with a hands-on activity, the teacher was guiding students by telling them how to use the materials (Van de Walle, 2004). Traditional mathematics teachers sought the correct answer to validate student understanding (Van de Walle, 2004; Posner, 1995; Brooks & Brooks, 1993).

Currently, the view of mathematical facts and procedures as isolated bits of information to be transmitted to passive students continues to be dominant in American schools (O'Brian, 1999; Stigler & Hiebert, 1997; U.S. Department of Education, 1996). Manouchehri & Goodman (1998) found 35 out of 66 middle school mathematics teachers' instructional practices resembled the traditional approach of paper and pencil and individual seatwork. Many students, who are exposed to a traditional teaching approach, view mathematics as an endless sequence of memorizing facts and procedures that make little sense to them (Battista, 1999; Stigler & Hiebert, 1999). Reports indicate, however, that some teachers take a much different approach to teaching by having their students investigate mathematical ideas (National Research Council, 2001a).

Constructivist

For the purpose of this study, constructivism will be defined as active learning where students engage in learner-generated inquiry with authentic experiences, collaborative investigations, discussions, and reflection (Wilen, Bosse, Hutchison, & Kindsvatter, 2004). A constructivist mathematics classroom can be described as one in which a teacher uses activities that rely heavily on primary sources of information and manipulative materials. In addition, teachers of mathematics who support constructivism generally behave in an interactive manner, mediating classroom interactions and discussions and highly valuing students' questions (National Council of Teachers of Mathematics, 2000; Windschitl, 1999; Brooks & Brooks, 1993). Typical classrooms with a constructivist approach seem to follow a routine. First, the teacher poses a problem in which students struggle to answer. Next, students present their ideas or solutions to the posed problem, and the class discusses the various methods used to solve the problem. Finally, the teacher states the conclusion, often using the words of the students (Wilen et al., 2004; California State University, 1997).

In some respects the origins of constructivism may be traced to John Dewey, late eighteen hundreds to early nineteen hundreds, who placed great emphasis on connecting to students' abilities, interests, and routines through the establishment of interactive, student-centered classroom environments (Dewey, 1938, 1998; Kliebard, 1995).
Lev Vygotsky placed even greater emphasis on the importance of socializing while students actively construct knowledge. Vygotsky asserted that knowledge could not be superimposed by adults and that the development of new cognitive structures is best facilitated in an interactive classroom environment (as cited in Gabler & Schroeder, 2003).

Even though numerous mathematics classrooms consist of a traditional teaching approach (Wagner, 1998; Stigler & Hiebert, 1999), a growing number of teachers are embracing the fundamental ideas of a constructivist learning approach (Loucks-Horsley et al., 2003; Mevarech, 1999; Ma, 1999). Teachers are beginning to realize that their students' background knowledge profoundly affects how they interpret subject matter, and students learn best when they apply their knowledge to solve problems (National Council of Teachers of Mathematics, 2000; National Research Council, 2000; Windschitl, 1999; Wagner, 1998; Brooks & Brooks, 1993). Students who engage in a constructivist approach in mathematics gain a deeper understanding of the concepts (National Council of Teachers of Mathematics, 2000; Mevarech, 1999; Wiske, 1998). For example, in a study involving one hundred seventy-four seventh grade students, using a 20-item two-step problem solving assessment, Mevarech (1999) found that those who were exposed to constructing strategy applications and connections significantly outperformed those who were exposed to direct instruction. In another study on the effects of seventh and eighth grade pre-algebra students who engaged in constructivist learning techniques not only scored higher on an achievement test than students who did not, but retained the information for a longer period of time (Whicker, Bol, & Nunnery, 1997). The idea of understanding is when students make mathematical connections between ideas, facts, or procedures (National Research Council 2000; Ma, 1999; Wiske, 1998; Hiebert & Carpenter, 1992). In summary, if students are to develop a deeper understanding of mathematics, the teacher must actively engage students in a constructivist approach (National Research Council, 2001a; National Council of Teachers of Mathematics, 2000). This would imply a need for a change and according to Stigler and Hiebert (1999), the most effective way to change and improve instruction is not in a short term workshop for teachers, but professional development that actually takes place in the classrooms with the teachers.

Professional Development

According to Darling-Hammond and Sykes (1999), the professional development of teachers is essential to improving the nation's schools. Educational standards encourage students to engage in complex problems that give rise to comprehensive mathematical understanding (National Council of Teachers of Mathematics, 2000). Many teachers will have to shift their beliefs of memorization, repetition, and recitation of correct answers to developing their students' reasoning and communication skills by actively engaging their students (Smith, 2001; Darling-Hammond & Sykes, 1999).

Educators cannot be expected to undergo such profound changes in their instructional strategies based on the professional development usually offered by school districts (Smith, 2001). For most teachers in the United States, professional development means attending a one-day workshop designed to transfer a specific set of ideas, strategies, or materials with little or no follow-up to facilitate classroom implementation (National Research Council, 2002a; Smith, 2001; Guskey, 2000). Even though the typical one-day teacher workshop is quite common, it is widely criticized as being ineffective in implementing change in classroom procedures (Garet, Porter, Desimone, Birman, & Yoon, 2001; Darling-Hammond & Sykes, 1999; U.S. Department of Education, 1998; Clarke, 1994). These one-day workshops tend to be disjointed and offer little opportunity for teachers to collaborate and reflect on practices with their colleagues (U.S. Department of Education, 1998). Teaching is still a largely isolated profession in which one educator rarely has the opportunity to connect in any powerful way to another. The teacher's workday normally consists of "working" with students with little time to engage in planning, reflection, and feedback with colleagues (Lewis, 2002a; Darling-Hammond & Sykes, 1999; Stigler & Stevenson, 1991). According to *Professional Standards for Teaching Mathematics* (National Council of Teachers of Mathematics, 1991), an essential factor in teachers' professional development is the degree to which they "reflect on learning and teaching individually and with colleagues" (p. 168).

Calls for improvements in professional development have strengthened over the last few years, with numerous "strategies" emerging to guide this endeavor (National Research Council, 2002a; Darling-Hammond & Sykes, 1999; Stigler & Hiebert, 1999). One growing consensus concerning professional development is the opportunity for teachers to engage in follow-up discussions with their peers (National Research Council, 2002a; Wilson & Berne, 1999; Clarke, 1994). A study conducted by the Southwest Educational Development Laboratory (Johnson & Blair, 1999) found group collaboration among teachers as a vital element in translating ideas into practice. For example, teachers ranked the sharing of their thoughts and ideas with their colleagues as a highly valuable part of their professional development. In addition, research has resulted in empirical support that collaboration among teachers provides learning opportunities and changes in classroom practice as well as sustained motivation for instructional change (Loucks-Horsley et al., 2003; Garet, et al., 2001; National Research Council, 2001a). Simply stated, many teachers believe that their main support in improving their instructional skills comes from other teachers but ironically, they have few opportunities to collaborate with their peers (Stigler & Hiebert, 1999; Clarke, 1994). Therefore, until teachers are encouraged and provided opportunities to collaboratively share ideas, strategies, and techniques, limited changes in the classrooms will occur (Wallace, Nesbit, & Newman, 2001; Smith, 2001; Morrissey, Cowan, Leo, & Blair, 1999; Darling-Hammond, 1998). The Japanese have found a means for addressing the call for collaboration among teachers through lesson study. The question then becomes whether or not the implementation of lesson study in the United States serve as a means for developing and supporting effective instructional strategies and result in deeper understanding of mathematical concepts along with strengthening achievement levels in mathematics for both students and teachers in America.

Lesson Study

Perhaps thousands of researchers in the country are studying teaching strategies (Stein, 2004); however, there are millions of teachers trying out new ideas and strategies in the classrooms in order to see what works or does not work. Yet, until recently, there was no mechanism for learning from the experiences in the classrooms (California State University, 1997). According to the National Research Council (2001a), the key to teaching and learning mathematics is the interaction among teachers, students, and instructional strategies. In the United States, teachers seldom plan lessons together, observe one another teaching, or collaboratively analyze instructional strategies and student understanding (National Research Council, 2001a; Stigler & Hiebert, 1999; Stevenson & Stigler, 1992). In 1999, Stigler and Hiebert's book *The Teaching Gap*, brought the account of Japanese lesson study to a large audience. According to Stigler and Hiebert the premise behind lesson study is simple: If the goal is to improve teaching, the most effective place to do so is in the context of the classroom lesson. By beginning with lessons, the problem of how to apply research and reform movements in the classroom disappears.

Lesson study can be defined as a teacher-led instructional improvement cycle in which teachers work collaboratively to: formulate goals for student learning, plan a lesson, teach and/or observe the lesson, reflect on the gathered evidence, revise the lesson for improvement, and re-teach the revised lesson (Perry & Lewis, 2003; Curcio, 2002). Through the use of lesson study, teachers have a means for planning, observing, and conferring with others (Lewis, Perry, & Hurd, 2004; Curcio, 2002; Lewis, 2002a,b; National Research Council, 2001a).

After the publication of *The Teaching Gap*, during 2000-2001, lesson study attracted more than 400 educators to observe lesson study sites in the United States (Lewis, 2002b). In February 2000, one of the first examples of lesson study in the United States took place at Paterson School Number Two in New Jersey (Lewis, 2002a, 2000a; Germain-McCarthy, 2001). This first public United States research lesson attracted many observers, and the benefits of Japanese lesson study were quickly recognized. One observer commented:

> This practice is in stark contrast to American classrooms where each teacher plans and teaches in almost complete isolation. When a brilliant American teacher retires, almost all the lesson plans and practices that he or she developed also retire. When a brilliant Japanese teacher retires, he or she has left a legacy to be enhanced by future teachers (Chenoweth, 2000, as cited in Lewis, 2002a, p. 6).

Currently, interest in lesson study is substantial due to particular characteristics that distinguish it from other professional development procedures (Lewis, 2002a). Lesson study has spread across the United States appearing in at least 250 schools in 29 states (Lewis, Perry, & Hurd, 2004). According to Takahashi and Yoshida (2004), lesson study offers certain characteristics that set it apart from "typical" professional development programs. First, lesson study provides teachers the opportunity to see teaching and learning as it takes place in the classroom. Second, lesson study keeps students at the heart of the professional development activity. Finally, lesson study is teacher-led professional development. Consequently, through numerous teacher interviews, classroom observations, and collaborative reflections research has shown that there are "seven key pathways to improvement that underlie successful lesson study: increased knowledge of subject matter, increased knowledge of instruction, increased ability to observe students, stronger collegial networks, stronger connection of daily practice to long-term goals, stronger motivation and sense of efficacy, and improved quality of available lesson plans" (Lewis, Perry, & Hurd, 2004, p. 2).

Even with this rapid spread of lesson study, there has been little public conversation about how teachers learn during lesson study (Lewis, Perry, & Murata, 2004). In fact, Japanese researchers say that despite lesson study's 100-year history in Japan, there are few if any substantial research studies of its effectiveness (Perry, Lewis, & Akiba, 2002).

In the United States where lesson study sites, such as Paterson School Number Two, are viewed to be successful based on interviews and observations, evidence relating to instructional improvement is still relatively small (Lewis, 2002a), but what is more limited is the fact that there has been little research investigating the effects of lesson study on student learning. Essentially, the question becomes what effects do lesson study have on teachers' beliefs in instructional practices and content knowledge as well as what effects do lesson study have on students' mathematical understanding and achievement?

Statement of the Problem

When American teachers are asked about their awareness of current ideas regarding the best way to teach mathematics, an overwhelming majority will answer that they are aware of these ideas. When American teachers are asked if they have implemented these ideas into their classrooms, an overwhelming majority will answer that they have implemented these ideas (Stein, 2004; U.S. Department of Education, 2003; Loucks-Horsley et al., 2003; California State University, 1997). However, when American mathematics classrooms are observed, an overwhelming majority appeared to have implemented new ideas merely on the surface level, meaning that the basic teaching philosophies of the teachers have not changed (U.S. Department of Education, 2003; Stigler & Hiebert, 1999). Accordingly, many classroom observations have revealed that teachers, while implementing new strategies and ideas, unconsciously transformed them into "an extension of the same basic approach to teaching they have always used" (California State University, 1997, p.15). As a result of classroom observations and international comparisons, studies have shown that American students are in need of deeper understanding of mathematical concepts and procedures (Boaler, 2002; Stigler & Hiebert, 1999), and American teachers are in need of deeper understanding of subject matter (Ma, 1999) and approaches for implementing effective teaching strategies into the classroom (National Research Council, 2001a; Council of Teachers of Mathematics, 2000; Atkins & Black, 1997; Stigler & Hiebert, 1997). Research has shown that effective professional development should involve teachers and be ongoing in order to provide follow-up and support for implementing teaching strategies (Loucks-Horsley et al., 2003; National Research Council, 2001a; Smith, 2001; Darling-Hammond & Sykes, 1999). Adopting the Japanese lesson study in the United States has been identified as a means to accomplishing the goal of improving teaching in the area of mathematics (Loucks-Horsley et al., 2003; National Research Council, 2002a; Stigler & Hiebert, 1999). According to Hiebert (1999), research on teacher learning shows the importance of collaboration among teachers for the purpose of improving lesson planning, student achievement, curriculum and pedagogy, and access to alternative ideas and procedures.

Although interviews and observations have shown that lesson study has resulted in increasing teachers' content knowledge, instructional knowledge, and collaboration among educators (Lewis, Perry, & Hurd, 2004; Lewis, 2000a; Lewis & Tsuchida, 1998), more studies must be conducted in the United States in order to understand the impact that lesson study has on instructional improvement and on student learning (Lewis, Perry, & Murata, 2004; Lewis, 2002a). In particular, more studies need to be conducted at the middle school level. In Japan, lesson study in mathematics is typically practiced at the elementary and middle grades (Stigler & Hiebert, 1999; Curcio, 2002); however, the majority of lesson studies in mathematics in the United States focus on elementary grades (Lewis 2002a,b). The middle grades are the bridge to developing students' conceptual understanding in mathematics (National Research Council, 2000; Hart, 2000).

From the TIMSS, results show United States fourth-grade students scoring above the average of the TIMSS countries. United States eighth-grade students, however, rank below the international average (National Research Council, 2001a; Stigler & Hiebert, 1997, 1999). According to the National Research Council (2000), middle grades are identified as the time students should move from the concrete to the abstract. As international comparisons suggest, American middle school teachers fall short in helping students make the transition from concrete to abstract (National Research Council, 2000, 2001a). There are strong indications that many American middle school teachers do not have the necessary background knowledge to help students conceptually understand abstract concepts in mathematics (National Research Council, 2000, 2001a; Ma, 1999). Therefore, middle school mathematics teachers must deepen their content knowledge and professional development is often viewed as the means to accomplish such a task (Smith, 2001).

As previously mentioned, lesson study has resulted in increasing teachers' instructional and content knowledge, but lesson study has a shallow history in the United States (Lewis, Perry, & Hurd, 2004). Consequently, more studies are needed in the United States to examine the connection between lesson study and teachers' beliefs about instructional practices, the effects on student learning, and the supporting conditions that are needed for lesson study to continue and grow in demand (Lewis, Perry, & Murata, 2004). Therefore, the researcher seeks to examine the following research questions:

Research Questions

1.0 What effects does lesson study have on middle school mathematics teachers?

- 1.1 What effects does lesson study have on middle school mathematics teachers' beliefs about instructional practices?
- 1.2 What effects does lesson study have on middle school mathematics teachers' content knowledge?

2.0 What effects does lesson study have on middle school students?

- 2.1 What effects does lesson study have on middle school students' mathematical understanding?
- 2.2 What effects does lesson study have on middle school students' mathematical achievement?

3.0 Does the participation in lesson study as a form of professional development serve as a catalyst for the growth and continuation of lesson study within the middle school mathematics community?

Definition of Terms

Lesson Study- A teacher-led instructional improvement cycle in which teachers work collaboratively to: formulate goals for student learning, plan a lesson, teach and/or observe the lesson, and reflect on the taught lesson (Perry & Lewis, 2003).

Research Lesson- The centerpiece of lesson study; an actual classroom lesson revised by a group of teachers participating in a lesson study (Lewis, 2002b).

Knowledgeable Other- A content specialist or a content educator who provides information about subject matter content, new ideas, or reforms (Watanabe & Wang-Iverson, 2002).

Mathematical Understanding- The comprehension of mathematical concepts, operations, and relations (National Research Council, 2001a).

Mathematical Achievement- The skill in carrying out procedures flexibly, accurately, efficiently, and appropriately (National Research Council, 2001a).

Professional Development- Those processes and activities designed to enhance the professional knowledge, skills, and attitudes of educators so that they will improve the learning of students (Guskey, 2000).

CHAPTER TWO

Literature Review

In 1983, the publication of *A Nation at Risk* sparked an alarmed interest in raising student performance, particularly in mathematics and science. Consequently, over the last two decades more and more attention has been brought to students' performance in mathematics not only on high stakes state assessments but in international assessments as well and the results show that student performance has been affected very little since the publication of *A Nation at Risk* (Burkhouse, Loftus, Sadowski, & Buzad, 2003; National Research Council, 2002b). As Americans became more concerned with student performance in mathematics, American schools experienced new instructional programs, the development of standards, curricula revisions focused on teaching materials, and standardized assessments. Yet, when compared to other countries, American students are still performing average to below average in mathematics (U. S. Department of Education, 2003). The main reason for little effect on students' mathematical performance is that too little attention has been paid to what actually goes on in the classroom and the effects of conventional approaches to professional development such as one-day workshops (Harwell, 2003). Therefore, the purpose of this study will be to focus on the impact of providing professional development for teachers of mathematics through the means of lesson study that effect their practices in ways that lead to improvement in student performance in mathematics.

This chapter will review the results of national and international comparisons in mathematics. As a result of students' low achievement in mathematics, attention has been brought to the instructional practices present in many United States classrooms as well as recommendations for a standards-based approach to teaching. Next, the researcher will review the importance of teacher content knowledge followed by a review on theories for effective professional development. The chapter will end with the research findings available on lesson study in the United States and the need for additional research.

National and International Mathematics Comparisons

The mathematics achievement of United States students has been of great concern among the public, educators, and education policymakers for years (Wang, Coleman, Coley, & Phelps, 2003). Under the leadership of former President Bill Eastland, Congress passed in 1994 *Goals 2000*, which stated that America was to be first in the fields of mathematics and science by the year 2000 (Goals 2000, 1994; Burkhouse et al., 2003; Ohanian, 1999). Under the leadership of President George W. Bush, Congress passed in 2001, the *No Child Left Behind Act* (NCLB) which calls for a highly qualified teacher in every classroom. According to NCLB, a highly qualified teacher is defined as full certification or licensure, a college degree, and demonstrated content knowledge in the subject being taught (NCBL, 2001; Smith, Desimone, & Ueno, 2005; Reeves, 2001). In addition, NCLB mandates that every state test students beginning in grade three and ending with exit exams in grade eleven (U.S. Department of Education, 2001). Currently, students are assessed at the state level as well as the national level in order to show achievement in mathematics. National student achievement in mathematics comes primarily from the National Assessment of Educational Progress (NAEP), often referred to as the *Nation's Report Card* (National Center for Education Statistics, 2005; Association for Supervision and Curriculum Development, 2003).

The assessment of students' achievement in mathematics has an extensive history at both the national and international level. In the mid-1990's, the most comprehensive study in mathematics and science to be analyzed in detail was the Third International Mathematics and Science Study (TIMSS). Over 40 countries participated in the TIMSS which is often referred to as the largest, most comprehensive, and most rigorous international comparison of education ever undertaken. Tests in mathematics and science, as well as questionnaires about their studies and beliefs were given to students at grades four, eight, and twelve. The TIMSS also included an examination of textbooks and curriculum guides from several countries as well as a video study of eighth-grade mathematics classes in three countries (National Research Council, 2001a). Mathematics scores for United States fourth graders were above the international average; however, results for eighth and twelfth graders were much weaker, with the United States twelfth graders among the lowest (Burkhouse et al, 2003; Stigler & Hiebert, 1997, 1999).

In 1999, the Third International Math and Science Study-Revised (TIMSS-R) used the TIMSS assessment frameworks and specifications, and collected data solely from eighth-grade students from 38 countries. The purpose was to follow-up on the eighth-grade results from the 1995 TIMSS. The data collected from the TIMSS-R included achievement data from the mathematics and science assessment, background questionnaires, and videotaped observations of actual mathematics and science lessons from various countries (U. S. Department of Education, 2003). Results indicated that United States eighth-grade students' scores in mathematics had slightly increased from the 1995 TIMSS and were higher than the international average; however, 14 of the 38 countries scored significantly higher than the United States' eighth grade students

(Tatsouka, Corter, & Tatsouka, 2004; U. S. Department of Education, 2003; Wang et al., 2003; National Research Council, 2001a).

In 2003, the Trends in International Mathematics and Science Study (TIMSS) assessed the achievement in mathematics for either fourth or eighth grade level students, or both, from 46 countries. The TIMSS provided a means to track changes in achievement over time (National Center for Education Statistics, 2004a). Similar to the 1999 TIMSS-R, United States eighth grade students scored slightly above average and exceeded 25 of the 44 participating countries. Two of the 46 participating countries assessed students only at the fourth grade level. United States eighth graders were outperformed by students in nine countries: five Asian countries and four European countries (National Center for Education Statistics, 2004a; Association for Supervision and Curriculum Development, 2003).

In 2003, the United States also participated in the Program for International Student Assessment (PISA). The PISA is the United States source for internationally comparative information on the mathematical and scientific literacy of students at the age of 15 (Association for Supervision and Curriculum Development, 2003). More specifically the PISA was measured in terms of students' capacity to: recognize and interpret mathematical problems encountered in everyday life, translate those problems into a mathematical context, solve and interpret the problems, reflect on the methods applied, and communicate the outcomes (Clarke, 2003). The results of the PISA generated similar results to the 2003 TIMSS. Once again, fifteen-year-olds in Japan displayed the highest mean scores in mathematical literacy, outscoring the United States' students (Association for Supervision and Curriculum Development, 2003; Clarke, 2003).

In 2005, targeted United States fourth and eighth grade mathematics students participated in the NAEP. The average mathematics scores showed continuous improvement for both fourth and eighth grade students since 1990. For example, at the eighth grade, the percentage of students at or above a basic level of mathematical understanding increased from 52 percent in 1990 to 69 percent in 2005. Likewise, the percentage at or above a proficient level of mathematical understanding increased from 15 percent to 30 percent (National Center for Education Statistics, 2004b, 2005; Association for Supervision and Curriculum Development, 2003).

Even though assessment scores for students at the eighth grade have increased over the past few years, United States' students have yet to reach the goal of first in mathematics and science. Whether students are assessed with a high stakes state, national, or international test, results have raised a concern related to the issue of how mathematical skills and concepts should be taught.

Teachers' Beliefs about Instructional Practices

For over a hundred years observers have glanced into U.S. classrooms and reporting that very little has changed over the years (Stigler & Hiebert, 1999; Simon, 1997; Papert, 1993; Wang & Lin, 2005; Hiebert, 2003). The most common form of teaching in the U.S. is recitation. Recitation is defined as the teacher leads the students through the lesson material by asking lower level questions that can be answered with a brief response or even one word. The teacher acknowledges the response as right or wrong and asks the next question. The cycle of question, response, acknowledgement continues at a quick pace until the material has been covered for the day (National Research Council, 2001a). Mathematics classrooms function by following a pattern generation after generation (Lampert, 1990). First, answers are given for the previous day's assignment. A brief explanation and demonstration of the new material, and problems are assigned for the next day. The remainder of the class is devoted to working on the homework while the teacher answers individual student questions (National Research Council, 2001a; Stigler & Hiebert, 1999; Papert, 1993).

In 1989, the National Council of Teachers of Mathematics (NCTM) made a historically important first step in changing the instruction of mathematics by recommending that mathematics be taught in very nontraditional styles (Germain-McCarthy, 2001; NCTM, 1991, 2000). The new approach to teaching mathematics should be to develop a deep understanding of mathematical concepts by having students collaboratively construct strategies for engaging problems that assist them in connecting new knowledge to prior knowledge (Mevarech, 1999; Whicker, Bol, & Nunnery, 1997; Germain-McCarthy, 2000). NCTM argued that if students were engaged in challenging mathematics, then they would become mathematically powerful by demonstrating their ability to explore, conjecture, reason logically, and apply different strategies (NCTM, 1989; Germain McCarthy, 2001).

In April 1996, the NCTM Board of Directors approved a revising and updating of the 1989 NCTM recommendations, often referred to as the Standards. This new revision was labeled "Standards 2000" (NCTM, 2000) with the final document as NCTM's *Principles and Standards for School Mathematics (PSSM). PSSM* does not serve as a national curriculum; however, the new Standards are recognized by teachers, researchers, administrators, parents and others as a driving force in the teaching of mathematics. *PSSM* consists of six principles, five content standards, and five process standards. The six principles address the characteristics necessary in providing a high-quality mathematics education for all. The principles are as follows:

- Equity: Excellence in mathematics education requires equity—high expectations and strong support for all students (NCTM, 2000, p. 12).
- Curriculum: A curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well articulated across the grades (NCTM, 2000, p. 14).
- Teaching: Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn (NCTM, 2000, p. 16).
- Learning: Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge (NCTM, 2000, p. 20).
- Assessment: Assessment should support the learning of important mathematics and furnish useful information to both teachers and students (NCTM, 2000, p. 22).
- Technology: Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students; learning (NCTM, 2000, p. 24).

PSSM describes five content standards to apply across grades Pre-K through 12. The content standards are: number and operations, algebra, geometry, measurement, and data analysis and probability. Each grade level is responsible for addressing the five content standards; however, each strand has a different level of emphasis in every grade band. For example, number and operations is heavily emphasized from pre-K to grade 5 and continues to be important in the middle grades but has a lesser emphasis in grades 9-12 (NCTM, 2000; Van de Walle, 2004).

NCTM's five process standards address the mathematical process through which students should acquire and use mathematical knowledge. The process standards provide guidance for mathematics learning and teaching (Van de Walle, 2004). The five process standards include:

- Problem-solving: Build new mathematical knowledge through problem solving (NCTM, 2000, p. 52). Problem solving should serve as a means through which students develop mathematical ideas.

- Reasoning and Proof: Students need to provide an argument or a rationale as an integral part to every mathematical answer (NCTM, 2000, p. 56).
- Communication: Students should be able to talk about, write about, describe, and explain mathematical ideas (NCTM, 2000, p. 60).
- Connections: Students need to be able to make connections within and among mathematical ideas as well as connect to the real world and to other disciplines (NCTM, 2000, p. 64).
- Representation: Students should understand symbolism in mathematics, along with visual aids such as charts, graphs, and diagrams (NCTM, 2000, p. 67).

The six principles and ten standards were written to represent a vision of not only what should be taught in mathematics but how. Consequently, there is increasing agreement on the importance of teachers employing more conceptual ideas in their teaching of mathematics and less focus on traditional procedural and computational strategies (Ma, 1999; Smith, 2001; National Research Council, 2002b; Smith, Desimone, & Ueno, 2005).

Overall, teachers' self-reports reveal that most are aware of the proposed changes by the NCTM for standards-based instruction (National Research Council, 2001a; Knapp & Sowder, 2004; Smith, Desimone, & Ueno, 2005). In fact, from 1993-1994 to 1999-2000, there was an increase in the amount of professional development teachers participated in that focused on subject matter content in order to enhance conceptual or standards-based instruction in the classroom (Smith, Desimone, & Ueno, 2005). As part of the TIMSS-R in 1999, several questionnaire items were designed to identify how teachers might have been influenced by current ideas regarding the teaching and learning of mathematics. At least 76 percent of eighth-grade mathematics teachers in the United States agreed that they were familiar with the current standards on teaching and learning mathematics and U.S. teachers expressed greater confidence that their lessons were in accord with current mathematical ideas and strategies than teachers in other countries

(U.S. Department of Education, 2003; Wang et al., 2003). Even though teachers report knowledge and implementation of the standards, classroom observations show otherwise. Results from the 1995 TIMSS Video Study and the 1999 TIMSS-R revealed that mathematics teaching in the United States continues to emphasize the execution of pencil and paper skills through demonstrations of procedures and repeated practices (National Research Council, 2001a; U.S. Department of Education, 2003).

The 2003 National Assessment of Educational Progress (NAEP) not only assessed fourth and eighth grade students in their mathematical achievement but also administered a questionnaire to the students and to the teachers. According to the 2003 NAEP participating eighth grade teachers, 79 percent spent “a lot” of class time learning skills and procedures needed to solve routine problems and 78 percent spent “a lot” of time learning mathematics facts and concepts. When eighth grade teachers were asked survey questions pertaining to NCTM’s process standards, discussed previously, only 42 percent of the teachers reported spending “a lot” of time learning how to communicate ideas in mathematics effectively. In addition, when asked how much time was spent on developing reasoning and analytical abilities to solve unique problems, only 51 percent of teachers reported spending “a lot” of time (National Center for Education Statistics, 2004b).

More importantly, only eight percent of eighth grade students reported working in small groups everyday while 45 percent reported never working in small groups. According to the participating NAEP eighth grade students, only six percent worked with objects such as rulers, counting blocks, and geometric solids on a daily basis with 40 percent never using manipulatives. When eighth grade students were questioned on their use of calculators, only 15 percent used a calculator daily while 40 percent reported never using calculators in their mathematics class (National Center for Education Statistics, 2004b).

Based on the previous data, even though teachers were aware of the NCTM standards, (U.S. Department of Education, 2003) the percentages support United States' mathematics teachers emphasize a traditional focus of individual practice of routine skills and computations (Goldsmith & Shifter, 1997). Therefore, if teachers claim to be aware of and teach according to the standards, why do so many mathematics classrooms appear to have changed little over the years?

According to the National Research Council, to many educators, "a standard is a statement describing what a person should know or be able to do" (2002b, p. 2). NCTM, however, defined a standard in a much broader sense. The term standard was meant to encompass student conceptual understanding in mathematics and a constructivist approach in teaching (Goldsmith & Shifter, 1997; NCTM, 2000; National Research Council, 2002b). Research on classroom strategies indicates that students have more opportunities to learn basic computational skills and procedures (Hiebert, 2003; National Center for Education Statistics, 2004b; Germain-McCarthy, 2001).

Educators and researchers suggest that if students are to learn mathematics for understanding, then new forms of mathematics teaching must be understood, accepted, and implemented into the classrooms (National Research Council, 2001b; Goldsmith & Shifter, 1997). Thompson in 1984 conducted a study on teachers' beliefs and relationship to change. The study focused on three experienced junior high teachers as case studies. One participant, Lynn, viewed mathematics as a series of facts to be verbally transferred from the teacher to the students. Lynn believed students learned primarily by observing the teacher's demonstrations and then independently practicing the procedures. A second teacher, Jeanne, viewed mathematics as a logical system of concepts and emphasized concepts and structures. Jeanne also saw mathematics as fixed and predetermined, but taught by emphasizing justification and reasoning with connections from past and future lessons. Kay, the third case study, viewed mathematics as a mental exercise and involved the students in problem-solving activities. Kay's instructional approach reflected a process-oriented approach that allowed students to discover relationships and properties in mathematics. Thompson's study as well as a similar study by Cooney and Shealy (1997) concluded that teachers' confidence and background in mathematics and mathematics education influenced their instructional approach to teaching mathematics.

Franke, Fennema, and Carpenter (1997), studied change in beliefs and classroom practice of 21 teachers over a four year period. The study began by the researchers helping the participants understand the development of children's mathematical thinking which then led to a connection between how children solve problems. Data was then gathered in three areas in order to study teachers' instructional change. The areas included: teachers' beliefs, classroom practice, and content knowledge. Teachers' beliefs were defined as beliefs explicitly stated by the teacher, either in the context of teaching or in the interviews which were then coded. Classroom practice was coded based on the teachers' creation of the classroom environment which included the following: allowed students' to creatively problem solve, actively listened to students' mathematical thinking, and made instructional decisions based on children's mathematical thinking. Information regarding teachers' knowledge was drawn from occurrences in the context of teaching or discussions on teaching. Researchers specifically analyzed the teachers' ability to connect their content knowledge to the strategies students use to solve problems. Results indicated 90 percent of the teachers became more cognitively guided and believed students could solve problems without having a strategy provided. In addition, teachers provided opportunities for students to discuss various solutions to mathematics problems while they listened. When researchers first assessed what influenced the teachers' change, beliefs and classroom practice, the evidence reflected a variety of sequences. Upon closer examination between beliefs and classroom practice, researchers found that when practice changed before beliefs, it was less significant. However, when change was significant, a shift in teachers' beliefs had to accompany or precede their instructional practice.

In a study by Manouchehri & Goodman (1998), 66 middle school mathematics teachers' implemented four standards-based curricula over two years. The purpose of the study was to determine what variable seemed to enhance or impede teachers' use of the materials. Data collection methods for the study included: classroom observations, surveys, and unstructured interviews with participating teachers, parents, principals, and district mathematics coordinators. Teachers were asked to implement the curricula as much as they felt was possible. All participants began the activities enthusiastically, but only 20 of the 66 participating teachers reported routinely using the curricula after five months. Results found that the more experience teachers had with teaching with a traditional approach, the more they questioned the value and relevance of the standards-based curricula. The data revealed that the teachers' content knowledge and their beliefs about instructional practices had the greatest influence on their implementation of a standards-based curriculum.

Based on the previous studies, teachers' instructional practices are most influenced by their beliefs in how students' learn and their content knowledge

(Thompson, 1984; Manouchehri & Goodman, 1998; Franke, Fennema, & Carpenter, 1997). Higher standards for student learning have prompted educators to re-think how instruction should look in order to teach concepts in depth to all students. To do so, teachers must have a deep understanding of their content areas and how students learn (Loucks-Horsley et al., 2003; National Research Council, 2001a).

Teachers' Content Knowledge

Much of education reform literature suggests that content knowledge is essential to learning how to teach subject matter in order for students to understand it (Ma, 1999; Smith, Desimone, & Ueno, 2005; Hill, Rowan, & Ball, 2005; National Research Council, 2001a). Conventional wisdom asserts "You cannot teach what you don't know" (National Research Council, 2001a, p. 373). According to the National Research Council, an academically rich environment begins with teachers who are knowledgeable in mathematics, knowledgeable of students, and knowledgeable of instructional strategies (2001a,b). Knowledge of subject matter with an understanding of instruction results in a highly effective teacher (Phillips, 2003; Hill, Rowan, & Ball, 2005). Research indicates that many United States teachers do not possess a deep understanding of mathematics (Mewborn, 2003; Ma, 1999; National Research Council, 2001a). Evidence suggests that teachers, particularly at the elementary and middle school grades, often have limited content knowledge (Smith, 2001).

In 1984, Thompson conducted a study involving three middle school teachers. Each teacher was viewed teaching a mathematics class on a daily basis for four weeks. Data was gathered through observations and interviews. The first participating teacher's conception of mathematics teaching revealed that the role of the teacher was to present content in a clear, logical and precise manner and that students learned best by attending to the teacher's explanations and asking questions. The second participating teacher professed views that the teacher should encourage student participation and inquiry in class; however, when observed, the teacher had a tendency to disregard students' ideas and suggestions. The third participating teacher reflected a view of mathematics as a subject which encouraged discoveries and relationships of mathematical ideas and procedures. Classroom observations showed students were frequently asked to make predictions and support their conclusions in the classroom of the third participating teacher. Results indicated the differences in instructional practices were related to teachers' knowledge of mathematics. The teacher who encouraged a discovery approach to learning was confident in her content knowledge where as the other two teachers lacked confidence in their understanding of mathematics.

Another study involving 252 pre-service teachers at five universities was conducted by Ball in 1990. Participants were administered a questionnaire which addressed the following areas: ideas, feelings, and understandings about mathematics; about teaching and learning mathematics; and about students as learners. In addition to the questionnaire, a small sample of participants was interviewed and observed throughout their pre-service program and into their first year of teaching. Results indicated that participants had significant difficulties with the conceptual understanding of division with fractions. For example, out of 35 teacher candidates, only four (11 percent) were able to describe an appropriate representation of 1 ¾ divided by ½. Twelve out of 35 teacher candidates (34 percent) actually described inappropriate representations, and 19 out of 35 teacher candidates (54 percent) were unable to even generate a representation for 1 ¾ divided by ½. Ball concluded that for students to develop mathematical understanding, teachers must also have a deep understanding of mathematics.

Liping Ma (1999) researched the question of whether or not teachers' knowledge of mathematics might directly affect mathematics teaching and learning. Ma's research focused on 23 elementary teachers from the United States who were considered "better than average" and 72 teachers from five Chinese elementary schools that ranged from very high to very low quality. The study consisted of answering interview questions on teaching a topic, responding to a student's mistake, generating a representation of a particular topic, and responding to a novel idea raised by a student. Each of the interview questions addressed four standard topics in elementary mathematics: subtraction with regrouping, multi-digit multiplication, division by fractions, and perimeter and area of a closed figure. Results showed that 77 percent of the U.S. teachers and 14 percent of the Chinese teachers displayed only procedural knowledge of subtraction by regrouping. Most of the U.S. teachers' knowledge of multi-digit multiplication was procedural where as most of the Chinese teachers displayed a conceptual understanding. While forty-three percent of the U.S. teachers correctly calculated the division of fractions, only one showed an understanding of the rationale underlying their calculations. One hundred percent of the Chinese teachers, however, correctly calculated. In addition, most Chinese teachers revealed a deeper understanding and rationale for their calculations. Instead of "invert and multiply," most Chinese teachers supported their conceptual understanding by stating "dividing by a number is equivalent to multiplying by its reciprocal" (p. 58). Finally, when teachers were asked to investigate the relationship between the perimeter and the area of a rectangle, most U.S. teachers did not investigate the relationship independently but consulted a mathematics text book where as the Chinese teachers explored the relationship with their knowledge of the formulas and their understanding that a square is a rectangle. Consequently, Ma concluded that if students were to improve in mathematics then teachers' knowledge of mathematics needed to improve.

Hart (2000) also indicated that teachers must have a deeper understanding of mathematics especially at the middle grades. According to Hart, middle grades are the time in which students should transition from concrete to abstract thinking based on Jean Piaget's periods of cognitive development. Around the age of 12, adolescents are able to think about abstraction and hypothetical concepts (Berger, 1988). Consequently, Hart indicated that in order for students to successfully make this transition, teachers must have a deep understanding of mathematics.

Fernandez, Cannon, and Chokshi (2003) conducted a study involving 16 fifth and sixth grade teachers and administrators from an urban school in New Jersey. These teachers were to collaboratively plan a mathematics lesson to be implemented in a fifth or sixth grade classroom. When teachers were asked to describe the sequence of the unit to be taught, the teachers quickly determined the area of rectangles should be taught prior to the area of triangles because that was the sequence in the adopted textbook. Once the unit sequence was established, the participating teachers decided to collaboratively plan the lesson on finding area of triangles. A debate on whether to first teach the area of a right triangle, a scalene triangle, or an equilateral triangle occurred between the teachers. In order to resolve the debate, a Japanese teacher, serving as the guide and content specialist, suggested students should first study a right triangle followed by a scalene triangle. The rationale for this sequence was because students can easily see the relationship between triangles and rectangles and calculate the area. Then if students cut a scalene triangle in half, it would result in two right triangles once again building on geometrical relationships. The American teachers did agree to the suggested order; however, numerous teachers had difficulty understanding the structured knowledge as a result of their own content limitations.

Hill, Rowan, and Ball (2005) also conducted a study to explore whether and how teachers' mathematical knowledge affected students' mathematical achievement. Researchers collected survey and student achievement results from 115 elementary schools during the 2000-2001 through 2003-2004 school years. Student data was derived from student assessments and parental interviews. Teacher data was gathered from an annual questionnaire and a log in which teachers recorded the amount of time devoted to daily mathematics, the mathematics content covered that day, and the instructional strategies used to teach that content. Researchers strove to address two key elements of content knowledge: "common" knowledge and "specialized" knowledge used in teaching mathematics. Results suggested that knowledgeable teachers positively and substantially affected students' learning of mathematics; however, the possibility remained that general knowledge in teaching produced these results rather than content knowledge. Consequently, researchers concluded that content knowledge and teaching knowledge were the most important factors in promoting student achievement in mathematics.

Data from the 2000 National Assessment of Educational Progress (NAEP) was analyzed by Smith, Desimone, and Ueno (2005) in order to explore the relationships among educational credentials, preparedness to teach content, participation in professional development, and use of standards-based instruction by middle school mathematics teachers to improve student learning. Results showed that teachers with an undergraduate mathematics degree emphasized procedural strategies. Teachers with undergraduate degrees in mathematics with preparedness to teach, and who had participated in content focused professional development emphasized conceptual learning more often. Teachers with more years of experience were also more likely to use conceptual strategies. Furthermore, the researchers' analyses indicated that teachers with stronger content knowledge were more likely to engage in increased amounts of procedural teaching as well as conceptual teaching rather than trade off one for another. These findings suggest that content-related professional development could be an influential component in increasing conceptual learning and teaching goals.

Theories on Effective Professional Development

If teachers are expected to change from a traditional teaching approach to a conceptual approach, then the basis of traditional professional development must undergo profound changes. For most teachers in the United States, professional development includes district sponsored one-day workshops which typically focus on the following: curriculum and performance standards; educational technology integration; and subject-area study for new instructional methods (Wang et al, 2003; Smith, 2001; National Research Council, 2001a). Linda Darling-Hammond and Deborah Ball (1998) contend,

> A great deal of what teachers encounter as professional development does not consider them as learners, is not designed to help them develop over time, does not focus on the content or students whom they teach, and does not offer opportunity for focused analysis and reflection. Moreover, most professional development is conducted at a distance from the materials and problems of teachers' work (p. 16).

To support instructional change in mathematics, new forms of professional development are needed for teachers.

A study conducted by Gearhart, Sage, Seltzer, Schlackman, Ching, and Nasir, (1999) involved 21 upper elementary mathematics classroom. Three groups were formed: The "Integrating Mathematics Assessment" (IMA), the "Collegial Support"

(Supp), and the "Traditional" (Trad). The nine IMA groups applied a problem-solving curriculum which provided teachers the opportunities to increase their knowledge of mathematics, their knowledge of students' conceptual understanding and problem-solving strategies, and their expertise with assessment. The seven Supp groups also used a problem-solving curriculum and had the opportunity to build a professional community where colleagues met regularly to discuss issues concerning the implementation of the curriculum. The five Trad groups used a skills-based approach taken from the textbook and were provided no staff development throughout the study. A pre and post assessment was administered to the participating students which allowed the researchers to compare how teachers' choices of curriculum and professional development opportunities impacted students' learning. Lessons were videotaped and field notes were recorded. Results indicated the IMA and Supp groups outperformed the Trad groups. In addition, findings indicated the need for teacher support. More importantly, evidence supported that professional development that was primarily aimed at offering collegial support without a focus on mathematics, students' mathematical thinking, or curriculum was not as effective in helping teachers change their instructional practices. Consequently, professional development that did focus on such topics had a greater impact on teacher instructional change.

In 2000, California's Mathematics Professional Development Institute (MPDI) undertook the largest content-focused professional development program in the United States by working with over 23,000 K-12 teachers in the first three years of the program. Teachers attended summer institutes of one to three weeks duration taught by mathematicians as well as mathematics educators. Teachers also participated in up to 80 hours of follow-up during the academic school year. Teachers were grouped by instructional levels such as elementary, middle, and secondary and focused on different mathematical content which ranged from number and operations to geometry. Hill and Ball (2004) focused on the 2,300 elementary teachers in their first efforts to use an instrument designed to measure teachers' content knowledge for teaching as an evaluation tool.

Garet, Porter, Desimone, Birman, and Yoon (2001) used a national probability sample of 1,027 mathematics and science teachers to provide a large scale comparison on the effects of professional development on teachers' learning. In order to assess high-quality professional development, three structural features were analyzed: whether the activity was reform type, the duration of the activity, and the degree of collective participation emphasized by the activity. In addition, professional development activities were analyzed by: the degree in which the activity improved or deepened teachers' content knowledge, the degree in which teachers' activity engaged in the analysis of teaching and learning, and the degree to which the activity promoted growth and collaboration in teachers' professional development. Results showed both content focus and coherence had positive effects on increasing knowledge and skills. Active learning, meaning students were engaged, was also revealed to enhance knowledge and skills; however, the effect was less strong. Teachers who reported enhanced knowledge and skills were likely to report changing their teaching practices as well. Results indicated that sustained professional development that focused on subject matter, and was integrated into the active daily life of school was more likely to enhance student knowledge and skills.

Evidence suggests that students learn best when they are required to construct their own knowledge (NCTM, 2000; Wiske, 1998; National Research Council, 2000).

Consequently, in order for students to construct their own knowledge, teachers can no longer adhere to their traditional role of transferring knowledge to the students but instead, teachers themselves must learn new ways of teaching. As research indicates that students learn best by constructing their own knowledge, teachers also have to construct their own knowledge in order to improve their instructional strategies (Kwakman, 2003; von Glasersfeld, 1981; Richards & von Glasersfeld, 1980).

Kwakman (2003) designed a study to define and explain teacher learning in the workplace. Professional learning was sorted into four categories: individual reading, doing and experimenting, reflecting, and collaborating. The first category had to do with professional reading as a means of keeping up to date with new insights influencing their professional field. Secondly, by doing and experimenting, teachers gain new experiences and ideas to improve their instructional practices. Third, reflection was viewed as a prerequisite in order to recognize and change routine behavior. The fourth category addressed collaboration which provides support for learning as well as teacher feedback and brings about new ideas and challenges. Interviews were conducted with sixteen secondary school teachers which were coded and categorized using a constant comparison method. Results revealed that learning may best be examined in connection to teachers' concrete tasks and daily activities; however, there was little feedback from classroom observations and limited sharing of materials and ideas. The main conclusion drawn was that even though the school environment is considered a powerful learning environment, it does not lend itself to collaborative planning and reflecting.

Linek, Raine, Fleener, Klakamp, and Fazio (2003) focused on shifting the professional development so that learning occurred by shared responsibilities and collaborative decision making in three elementary schools. This was accomplished by offering professional development based on teachers' needs. The professional development then took on a unique look by having individual teacher's participation in off-campus training and then provided campus training to other faculty members by forming on-campus study groups. In addition, students became the focus of the shared decision-making process. Data were gathered over a five-year period consisting of teacher interviews, observations, and artifacts using a constant comparative method of qualitative analysis. Student achievement was tracked from 1993-94 to 1997-98 based on the Texas Assessment of Academic Skills (TAAS). Data was gathered for approximately 100 students for each of the three sites and results showed increases throughout the years at all sites. The findings support that professional development is an excellent avenue to improve student achievement. The findings further support the call for collaborative planning and reflection among classroom teachers. Caution was advised in interpreting and over-generalizing results based on a statewide assessment. The researchers advocated the need for further research to be conducted in order to determine the impact on-campus professional development has on student achievement.

Linek et al. research findings called for more studies on the effects of on-campus professional development and student achievement. Phillip's (2003) in her research focused on an urban middle school in order to investigate high-quality professional development for teachers and its impact on student achievement. This particular school was one of 88 schools participating in a school-based reform initiative where the middle school teachers participated in study groups. The teachers began with departmental study groups consisting of three or four teachers who shared their experiences, challenges, and resources. As a result of shared leadership and the commitment to develop effective learning communities, this middle school put improving teacher learning at the center of its reform work. Second, administrators and teachers sought new idea sources to help them connect theory and practice. Third, teachers developed strong decision-making voices and shared in the leadership. Fourth, administrators and teachers collaborated on individual learning plans and feedback on instructional practices. Finally, teachers created learning environments and experiences that were more meaningful to the students. Throughout this five-year process, students moved from a state rating of acceptable, indicating at least 50 percent of all students passing, to the highest rating of Exemplary, indicating that 90 percent of all students were passing. Evidence suggested that as a result of teachers engaging in their own learning, students' academic achievement increased.

Prior to the Hill and Ball (2004) study, the only existing measures of teachers' content knowledge in mathematics consisted of interviews and open-ended written responses; however, this study used a pre and post evaluation with a reliability of 0.7 or more. The validity of the assessment is on-going. The researchers, however, caution that the results should be thought of as tentative because teachers had an option to participate in the pre and post evaluation and consequently, data was collected on only 398 teachers. The average teacher score on the pre-test was 0.47 for the average item difficulty, and the average on the post-test was 1.06, for a gain of 0.48 which indicated a significant difference at ($p < 0.0001$). The results indicated that teachers could learn mathematics for elementary school teaching within the context of a single professional development program. Results also indicated that even though teachers' content knowledge did improve, there was less success in improving teachers' instructional activities. Therefore, research suggests professional development in content knowledge must also address instructional strategies.

Based on the previously discussed studies, professional development that focused on content knowledge and instructional practices resulted in increased changes in the classroom (Hill & Ball; 2004; Gearhart et al., 1999; Garet et al., 2001; Wang et al., 2003). Professional development that occurred in the school environment and encouraged collaboration among teachers and administrators had positive results in effecting teacher change as well (Kwakman, 2003; Linek et al., 2003; Phillip, 2003). Guskey (2000) also supported four common elements to successful professional development efforts. First, there had to be a primary focus on issues related to learning and learners. In other words, successful programs were related to long term goals such as a school's mission statement. Second, organizational and systemic changes were essential. Teachers needed opportunities to speak publicly about their teaching and to participate in decisions with their colleagues and administration regarding instructional matters. Next, the greatest successes were found with sustained efforts and occurred in small, incremental steps. Finally, professional development was not an event that was separate from one's day-to-day professional routine. Successful professional development was on-going and embedded in the process of developing lesson, instructional activities, and student assessments (National Research Council, 2002b; Greeno, 2003).

The Japanese's form of professional development consists of the elements researchers such as Thomas Guskey (2000) recognized as essential elements to positively influence instructional practices and students' understanding. Japanese teachers have accomplished increasing teachers' content knowledge and instructional practices by assuming primary responsibility for the improvement of instruction and student understanding. Teachers are the key to changing the way students learn mathematics

(Dana & Yendol-Silva, 2003; Darling-Hammond, 1998) and research indicates that by allowing teachers to construct their own learning while in their classroom environment instructional practices and student achievement improves (Phillips, 2003).

Kounaikenshuu is the Japanese word used to describe the on-going process of school-based professional development with the most common component being *jugyokenkyu*, which is composed of two words: *jugyo*, meaning lesson, and *kenkyu,* meaning study or research (Fernandez & Yoshida, 2004). According to Stigler & Hiebert (1999), through lesson study, teachers are able to collaborate, implement new lessons and instructional strategies while on their campus, and focus on content understanding and student achievement.

Lesson Study in the United States

Lesson study is a Japanese form of professional development consisting of the study or examination of teaching practice (Fernandez & Yoshida, 2004). The idea behind lesson study is simple. If instruction is to improve, then collaborating with fellow teachers to plan, observe, and reflect on lessons is essential (Lewis, 2002b; Stigler & Hiebert, 1999). The steps to lesson study are described as follows: identify goals for student learning and long-term development, collaboratively plan instruction for a research lesson, one teacher teaches the research lesson while others observe, reflect on the research lesson, and possibly re-teach the lesson (Lewis, 2002b; Stigler & Hiebert, 1999; National Research Council, 2001a; Perry, Lewis, & Akiba, 2002).

The 1995 and 1999 video analyses of eighth-grade mathematics lessons in the United States, studied after the Third International Mathematics and Science Study (TIMSS), and the Third International Mathematics and Science Study Repeat (TIMSS-R) revealed that U. S. eighth grade students were out performed by numerous countries. The video analysis also showed that Japanese teachers had a very different approach to their mathematics instruction (U. S. Department of Education, 1996; U. S. Department of Education, 2003). Considering the Japanese eighth grade students scored in the highest percentages, many U. S. educators became interested in the instructional strategies and designs of the Japanese mathematics lessons. Stigler & Hiebert (1999) introduced lesson study to the United States on a large-scale in their book entitled *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom*. Consequently, the interest in lesson study as a form of professional development began attracting much attention.

One of the first groups of U. S. teachers to engage in lesson study was from an elementary school in New Jersey. In the spring of 1997, the principal and several teachers from Paterson School Number Two, in New Jersey, attended a workshop and viewed the videotapes from TIMSS of mathematics lessons being taught in the United States and Japan. Some of the participating teachers became defensive but others were intrigued by the different approach to teaching. Consequently, two teachers spent that summer developing Japanese-style mathematics lessons and in October 1997, a group of ten volunteer teachers and their principal formed a mathematics study group. The group met for one 80-minute session per week during the school day to plan, observe, reflect, and revise lessons. In 1998, the Paterson School Number Two was introduced to lesson study through the article *A Lesson Is Like a Swiftly Flowing River* (Lewis & Tsuchida, 1998; Lewis, 2000a). Teachers from Paterson School Number Two sought help from Clea Fernandez and Makoto Yoshida who were lesson study researchers. On February 28, 2000, Paterson School Number Two hosted the first United States public research lesson. The research lesson was planned by four teachers and taught to nineteen second graders. The research lesson began by posing a multiplication problem to the students who became so involved with the task that they postponed eating candy bars in order to solve another problem. According to Lewis, it is too early to assess the effect of lesson study, however, based on achievement test data and the number of elementary students engaged in algebra at Paterson School Number Two supports improvement in instruction. More importantly, lesson study was brought to life in the United States and teachers found it useful (Lewis, 2002b).

During the summer of 2000, four mathematics teachers from the San-Mateo-Foster City School District in California became aware of lesson study as a result of a workshop that focused on the TIMSS video-study (Perry, Lewis, & Akiba, 2002). Together, these teachers requested and received release time from the district and stipends for lesson study volunteers. During fall of the 2000-2001 academic school year, seven lesson study groups were formed from 28 participating teachers (Lewis, 2002b). The lesson study groups were formed in order to accomplish four goals: more effective professional development model, teacher collaboration, improved instructional strategies, and increased students' mathematical understanding (Perry, Lewis, & Akiba, 2002).

At the beginning of the 2000-2001 academic school year, one day of professional development was dedicated to introducing lesson study to the San Mateo teachers. Teachers were then asked to form small lesson study groups by grade levels and begin by selecting a topic for their research lesson. Each group then planned their lessons collaboratively, except for one, in which the lesson was planned by the teacher who was going to teach it. All groups did debrief after the research lesson and then either made changes and re-taught the lesson or began working on a new topic for a second research lesson (Perry, Lewis, & Akiba, 2002).

Interview results from the participating teachers revealed that finding time to do lesson study was a challenge and selecting a topic for the research lesson proved to be challenging as well. Every participating teacher mentioned the value and usefulness of collaboration with their peers and appreciated the observation component of lesson study. In addition, the ability to observe and reflect collaboratively with other professionals allowed teachers to establish common understandings in order to improve lessons (Perry, Lewis, & Akiba, 2002).

After the first year of lesson study, recruitment was easier by the testimony of teachers who had participated in lesson study. In addition, San Mateo teachers were able to collaborate with six experienced Japanese teachers on lesson study. The district also opened its doors for a lesson study open house in spring, 2002, so that others could view the now 58 participating teachers in the San Mateo lesson study groups (Lewis, 2002b; Perry, Lewis, Akiba, 2002).

After year two, participating teachers said that lesson study had strengthened their knowledge in understanding the flow and continuity of a lesson. For example, does the lesson build toward conceptual understanding? Does the use of manipulatives enhance or distract students from the intended lesson goals? Teachers also commented on the importance and value of letting students discover their own answers in order to promote deeper conceptual understanding (Perry, Lewis, & Akiba, 2002).

By year three the San Mateo lesson study groups had increased to 78 teachers and while researchers say more studies are needed to determine the impact of lesson study, three types of essential elements became evident. First, a lesson study cycle needs to be well balanced, coherent, and responsive to local needs. Next, lesson study groups must have access to a “knowledgeable other” who has excellent content knowledge. Finally, participants must have personal and collegial qualities that support learning (Perry & Lewis, 2003; Lewis, Perry, & Murata, 2004).

Lewis, Perry, and Murata (2003) studied three lesson study groups in order to address the relationship of lesson study to teachers' knowledge development. The first group consisted of five 3rd grade teachers who focused on number sense and problem solving. Data was collected through pre and post lesson study interviews, observations during planning sessions, written observation notes, and teacher reflection forms. The gathered data revealed the progression in the teachers' thinking as well as opportunities to learn about the difficulties students were having with problem solving.

The second lesson study group consisted of three kindergarten teachers who selected the use of concrete objects to determine the answers to addition and subtraction problems as their research topic. Results showed that the teachers were able to share, discuss, and clarify their understanding for the topic to be taught. Consequently, the teachers expressed confidence and excitement about teaching the concept and predicting students' questions and responses. During reflection time, teachers commented that the key to their understanding of student thinking and the concept was seeing the students' success (Lewis, Perry, & Murata, 2003).

The third lesson study group consisted of six elementary teachers who planned, taught, revised, and re-taught a research lesson within two weeks. The research topic was to focus on patterns as a foundation for algebraic thinking. Evidence collected for this study focused only on the planning phase; however, results indicate that teachers were able to connect their own conceptual difficulties to students' difficulties (Lewis, Perry, & Murata, 2003).

In 2001, thirty Los Angeles teachers were trained in lesson study. These teachers were observed, interviewed and surveyed to determine their thoughts about lesson study and the impact it had on student learning. Results showed that above all, teachers valued the collaboration with colleagues. In addition, 96 percent of the teachers agreed that lesson study enabled them to improve the taught curriculum, and 92 percent reported that lesson study enhanced their confidence and creativity. Eighty-eight percent of the teachers stated that lesson study resulted in them being better teachers and 80 percent reported they felt more like professionals. Teachers also reported that they believed lesson study helped all students learn, and teachers were unanimous in their desire to see lesson study continue and expand (Wilms, 2003).

As lesson study gains support, more participants from middle and secondary schools need to participate. Watertown High School is one in a limited number of secondary schools engaged in lesson study. In 2000, Jane Gorman, June Mark, Al Cuoco, and Michelle Manes (Education Development Center, 2002) began lesson study with four mathematics teachers from Watertown High School. Watertown is a culturally diverse community nine miles west of Boston. By the 2001-2002 academic school year, the entire Watertown High School mathematics department was participating in lesson study. Currently, Gorman and others are working not only with Watertown High School, but an additional 20 lesson study groups in the Eastern Massachusetts region. Teams consist of three to ten secondary mathematics teachers. The project phased in seven teams during fall 2002, spring 2003, and fall 2003. Each team was provided support through the Education Development Center for two years of participation in lesson study. Out of the 21 lesson study teams, there were 16 high school teams and five middle school teams. The research for this secondary lesson study project involved the administration of a baseline survey along with follow-up surveys in order to gather background information on all participants as well as ascertain variations within the sample. Observations were made on the full lesson study cycle for three teams. In addition, ten participating teachers were interviewed in order to provide a clearer picture of the lesson study work. This is one of the few lesson study projects to include middle schools and as to date, results from this study have not been reported.

Lessons Studied, Lessons Learned is a mathematics and science partnership grant awarded to the Macomb ISD in partnership with Oakland University by the Michigan Department of Education. The *Lessons Studied, Lessons Learned* grant is focused on middle school mathematics with the following goals:

- To deepen middle school mathematics teachers' content knowledge
- To increase teacher collaboration and knowledge of best practices
- To increase the number of "highly qualified" middle school mathematics teachers
- To improve middle school students' performance in mathematics as related to the state assessment

There were five middle school mathematics lesson study groups during the 2004-2005 academic school year. Each group consisted of approximately six classroom teachers, a facilitator, and a "knowledgeable other." To date, each of the lesson study groups' lesson plans for the research lessons were made accessible for others to view; however, the impact lesson study had on achieving the previously mentioned goals has yet to be reported (http://www.misd.net/lessonstudy/resources.htm).

Since 1999, there has been an increased interest in lesson study as a form of professional development that improves instructional strategies (Lewis, 2002b; Loucks-Horsley et al., 2003; National Research Council, 2001a). Catherine Lewis, from 1996-

2000, interviewed 75 Japanese teachers and administrators regarding lesson study and its impact on instruction (Lewis, 2000a). Responses indicated that lesson study allowed the teacher to think carefully about the goals and connections of the lesson as well as the realization that instructional approaches influence academic and social development. Japanese teachers also responded that through collaboration they were able to have access to the best possible lessons in addition to deepening one's content knowledge. Finally, lesson study allowed the teacher to see instruction through the eyes of the student resulting in better understanding of instruction (Lewis, 2002b, 2003; Lewis, Perry, & Hurd, 2004).

Conclusion

Researchers believe that educators in the United States are interested in lesson study because it allows teachers to view teaching and learning as it occurs in the classroom. Lesson study also keeps students as the main focus. A third reason is that lesson study is teacher-led which allows teachers to be actively involved in instructional change (Takahashi & Yoshida, 2004; Guskey, 2000; Wilms, 2003).

Interestingly enough, even as more educators are becoming aware of and participating in lesson study, there is limited documented evidence on its effectiveness, particularly at the middle and secondary levels (Lewis, 2002a; National Research Council, 2001a; Fernandez, Cannon & Chokshi, 2003). The limited evidence available suggests that at some sites, United States' teachers have found lesson study useful (Lewis, 2002a, 2003; Lewis, Perry, Hurd, 2004; Wilms, 2003; Lewis, Perry, & Murata, 2003; Lewis, 2000b; Perry, Lewis, & Akiba, 2002); however, more evidence on the impact lesson study has on teachers and students is needed (Lewis, 2000a, 2002a). As lesson study becomes more recognized in the United States, the focus is no longer on how to conduct lesson study, but how to conduct it more effectively. In addition, Lewis (2003) begs the question, of whether or not lesson study is simply the latest educational innovation and will quickly be discarded like numerous other once-promising practices. Therefore, for teachers who do participate in lesson study, will this serve as a catalyst for continuous participation and future growth? The research is inconclusive in determining the effects lesson study has on teachers' instructional strategies and conceptual knowledge as well as the effects on student's achievement and conceptual understanding. Consequently, more studies are needed in order to identify the impact of lesson study in the United States and its future existence (Lewis, 2000a; Lewis, Perry, & Murata, 2004).

CHAPTER THREE

Research Methodology

This study examined the effects of lesson study on middle school mathematics teachers and students by investigating the effects of participation in lesson study on teachers' beliefs about instructional practices and their content knowledge along with its effects on students' mathematical achievement and understanding.

The purpose of this chapter is to describe (a) the design of the study, (b) the research questions addressed, (c) the context and description of the participants of the study, (d) the procedures used to gather data, and (e) the methods used to analyze the data.

Research Perspective

This study used a qualitative approach to data collection using a constant comparative analysis involving multiple case studies. The two stages of analysis involved in a multiple case study consisted of both a within and across case comparisons. For the within-case analysis, each case was first treated as a comprehensive case in and of itself. Consequently, once the analysis of each case was completed, a cross-case analysis began in order to develop more sophisticated descriptions and more powerful explanations (Merriam, 1998). An analytic induction analysis method was used where the categories emerge from reading and analyzing various data points from recorded meetings, observations, and reflections. In order to code the arising categories, an open coding approach was used, and then as patterns emerged from the analysis, axial coding was used to identify subcategories in order to develop the emerging themes and concepts.

Qualitative Research

Given the number of factors that may affect teachers' beliefs regarding instructional practices, case studies consisting of teachers who participated in lesson study were examined in an attempt to identify factors that influenced beliefs about instructional strategies and mathematical understanding. A case study, as defined by Stake (as cited in Creswell, 2003), is an in-depth exploration of a program, an event, an activity, a process, or one or more individuals in which the case(s) are bounded by time and activity. The current study examined the influences that lesson study had on teachers' beliefs about instructional practices as well as teachers' content knowledge using qualitative measures of surveys, written notes, electronic discussions, written lesson plans, observations, videotapes, and reflections.

Research Questions

The overall research addressed the questions of what effects lesson study had on teachers and students. The first question focused on (a) the effects of lesson study on teachers' beliefs about instructional practices and (b) the effects of lesson study on teachers' mathematical content knowledge. The second question focused on (a) the effects of lesson study on students' achievement in mathematics and (b) the effects of lesson study on students' conceptual understanding in mathematics. The third question focused on factors that influenced the growth and continuation of lesson study within the targeted mathematics community.

1.0 What effects does lesson study have on middle school mathematics teachers?

1.1 What effects does lesson study have on middle school mathematics teachers' beliefs about instructional practices?

1.2 What effects does lesson study have on middle school mathematics teachers' content knowledge?

2.0 What effects does lesson study have on middle school students?

2.1 What effects does lesson study have on middle school students' mathematical understanding?

2.2 What effects does lesson study have on middle school students' mathematical achievement?

3.0 Does the participation in lesson study as a form of professional development serve as a catalyst for the growth and continuation of lesson study within the middle school mathematics community?

Context

This study took place in an urban school district in central Texas in its sixth year of a grant, awarded nationwide by the United States Department of Education to help disadvantaged students prepare for and gain an avenue to undergraduate programs. This study's urban school district partnered with a private university, a technical college, a county youth collaborative, and a city foundation in the initiative, Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP), to ensure that all students in the urban school district had access to rigorous courses that prepared them for college as well as provide a support system dedicated to providing urban students and their parents the inspiration and information necessary for a successful transition to college (Wilkerson, personal communication, September 14, 2004). In 1998-1999, this urban school district and a local private university engaged in a five-year partnership to engage middle school mathematics students and teachers in mathematical explorations and investigations as well as support for mathematics instruction which became known as the GEAR UP Math Initiative. On average, 20 middle school mathematics teachers and approximately 60 middle school students engaged in mathematical investigations twice a year at the private university.

According to the Texas Education Agency (TEA) (2003), this participating school district is comprised of approximately 15,600 students. Of these students, 25.7% were in high school, 21.4% in middle school, and 39.2% in elementary school. The district consists of three high schools, seven middle schools, 19 elementary schools, and one alternative school. Student demographics for the district are as follows: 37% African American, 45.7% Hispanic, 16.8% White, and 0.5% other with 80.8% of economically disadvantaged status. According to the local school district's data, teacher demographics are as follows: 19% African American, 6.6% Hispanic, 73.5% White, and 0.9% other (Patterson, personal communication, October 1, 2005).

Participants

Approximately twenty three middle school mathematics teachers, facilitators, and administrators from seven middle schools within the urban school district in central Texas participated in a lesson study group. Five lesson study groups were formed. This study focused on a sub-set of three lesson study groups which consisted of 13 middle school mathematics teachers representing five of the seven middle schools. These teachers were identified through a criterion based purposeful sample approach (Gay & Airasian, 2000) in that they met the following criteria: middle school mathematics teacher in the study's identified school district, participated in the study's GEAR UP Math Initiative, and were assigned different "knowledgeable others" who guided them through the lesson study cycle. Participating teachers were grouped based on a needs assessment. One teacher from each group volunteered to teach one of his/her identified classes the research lesson. Therefore, approximately 60 middle school mathematics students participated in this study. Since classes were already formed, a convenience sampling of students was used. Convenience sampling involves the use of volunteers and the use of exiting groups simply because “they are there” (Gay & Airasian, 2000).

Demographic data was collected on each participating teacher. In addition, demographics were collected on the three participating middle schools. Table 1 describes all participating teachers by gender, ethnicity, age, education, and teaching experience. Table 2 describes the participating teachers for each case study by gender, ethnicity, age, and teaching experience. Table 3 describes the students from each of the middle schools hosting the lesson studies by ethnicity and state assessment scores.

Procedures

First Lesson Study Cycle

Full-Day professional development session. On October 16, 2004, approximately 26 middle school mathematics teachers, from seven middle schools, participated in a six-hour professional development session on lesson study at the collaborating private university. An agenda outlining the professional development session can be found in Appendix A. Participants spent the first 30 minutes with an overview of the day and completed two baseline surveys: Teacher Background Information (Appendix B) and Mathematics Teacher Survey (Appendix C). Following the completion of the necessary forms, the next 30 minutes was spent on participants identifying a research theme based on the qualities they would like their students to have five years from now. Following the identification of research themes, the next 60 minutes was spent with participants engaging in a needs assessment in mathematical content areas. School groups analyzed

Table 1

Teacher Demographics for Lesson Study Participants

Description	Participated (n=13)
Gender	
Female	9
Male	4
Ethnicity	
Caucasian	7
Hispanic	1
African-American	5
Other	0
Age	
20-29	3
30-39	3
40-49	2
50+	5
Education	
Bachelors	12
Masters	1
Doctorate	0
Years Teaching	
0-5	4
6-15	4
16-25	3
26-35	2
Teaching Math	
0-5	5
6-15	3
16-25	3
26-35	2

Table 2

Teacher Demographics for the Three Case Studies

Description	Case Study B (n=4)	Case Study C (n=4)	Case Study D (n=5)
Gender			
Female	3	3	3
Male	1	1	2
Teacher Ethnicity			
Caucasian	0	3	4
Hispanic	0	0	1
African-American	4	1	0
Age			
20-29	0	1	2
30-39	0	2	1
40-49	1	1	0
50+	3	0	2
Years Teaching			
0-5	1	1	2
6-15	1	2	1
16-25	1	1	1
26-35	1	0	1

Table 3

Student Demographics for the Three Case Studies

Description	Case Study B (n=310)	Case Study C (n=437)	Case Study D (n=461)
Student Ethnicity			
Caucasian	6%	12%	30%
Hispanic	55%	55%	36%
African-American	39%	33%	33%
2005 Passing State Assessment			
6^{th}	32%	44%	65%
7^{th}	32%	40%	62%
8^{th}	36%	79%	32%

district curriculum expectations, district test results, and state assessment results in order to identify key areas to be addressed. Each school group then shared results with the whole group in order to examine commonalities and differences. Each school group was then asked to select a content topic to address in their lesson planning and to regroup based on topic interest. Next, a specialist in the area of lesson study, from a national regional consortium, Southwest Educational Development Laboratory (SEDL) introduced the concept of a knowledge package as a guide in helping them in their research of their identified concept topic. For the next 75 minutes, participants researched the identified content area using sources such as the Internet, district textbooks, district curriculum documents, standards-based curriculum resources, and other supporting elements located at the collaborating private university. Participants were then engaged in a working lunch, where they shared their research findings. Over the next 90 minutes, the SEDL representative then provided the history, procedure, and goals of lesson study as well as had participants view a video of Oklahoma teachers who participated in lesson study. Participants then spent approximately 30 minutes discussing their views on lesson study. During the last 60 minutes, each group was assigned a "knowledgeable other" who would facilitate the group throughout the study. A "knowledgeable other" was a content expert and university faculty member from the local private university (Loucks-Horsley et al., 2003). Participants also received instructions on how to use an electronic discussion board, scheduled their next two-hour lesson planning session, received completed instructions on how to document the Teacher Log (Appendix D), and an evaluation form for the professional development (Appendix E).

Two-Hour planning session. Within three weeks following the six-hour professional development session, each participating group met for a two-hour planning session with their assigned "knowledgeable other," who served as the facilitator (Appendix F). Each group completed a plan for the research lesson that included the following elements: the aims of the lesson, the learning process for the lesson, the evaluation for the lesson, and copies of lesson materials (Lewis, 2002b). In addition, participating groups determined which group member would voluntarily teach the research lesson. At the conclusion of the session, group members who would observe during the research lesson determined their observation roles and reviewed the observation procedures. Consequently, the classroom in which the research lesson was to be observed was selected by the teacher who volunteered to teach the research lesson. Either a Master's graduate student in the School of Education at the collaborating private university or the researcher observed and took hand-written notes at each of the planning sessions.

Research lesson observation session. On the day in which the research lesson was to be conducted, no later than December 3, 2004, the lead teacher taught the lesson while team members and visitors observed and collected data agreed upon in advance (Appendix G). For example, one observer of the research lesson recorded all class statements and questions asked by the teacher. Another observer recorded all class comments and questions asked by the students. A third observer recorded what was written on the chalkboard, overhead, or *PowerPoint*. All other observers recorded how particular students or groups worked on the task as well as their comments and questions. Each of the three research lessons was videotaped.

Two-Hour reflection session. On the day in which the research lesson was conducted, a two-hour reflection session on the research lesson was held at an agreed upon time by the group (Appendix H). During the lesson reflection, a Master's graduate student from the School of Education at the collaborating private university or the researcher was present to take notes as well as videotape the discussion for transcription. During the reflection session, the lead teacher spoke first, for approximately five minutes, reflecting on the lesson implementation, noting what went well, and on any difficulties in the lesson before others shared their reflections. Next, members who planned the lesson shared, for approximately 20 minutes, reflecting on the goals for the students and the design of the research lesson, comparing and contrasting what was planned and what was observed. The discussion focused on the specific data collected by each observer. The general discussion involving the specific data collected by the observers required approximately one hour. The "knowledgeable other" who observed the research lesson provided feedback and shared in the discussion for approximately 20 minutes. Participants closed the reflection session by completing the Mathematics Teacher Survey (Appendix C) and turning in the following items: teacher log, lesson plan, instructional materials, seating chart, and written observation notes.

Students' work from the research lesson was collected from the lead teacher and used to analyze students' understanding in mathematical content following the research lesson. In order to analyze student achievement in mathematics, the lead teacher administered the district second nine weeks benchmark assessment, and the researcher analyzed the questions related to the research lesson.

Second Lesson Study Cycle

Second follow-up professional development session. In February, 2005, all middle school mathematics teachers, from the seven middle schools, were invited to participate in two three-hour professional development sessions. The first session focused on having the participants share their group experiences and results from the fall semester for approximately 90 minutes. The sharing of experiences was facilitated by the GEAR UP project director. The sharing time served as a basis for introduction to lesson study for new participants who attended the professional development. Following the reflection time, participants engaged in a review of the use of electronic discussion boards by addressing the following two areas:

- Please explain in what ways lesson study did or did not allow you to deepen your content knowledge.
- Please explain in what ways lesson study did or did not enable you to develop or strengthen your instructional knowledge.

The second three-hour professional development session focused on beginning a second lesson study cycle. The researcher began the session by reviewing the phases of the lesson study cycle through the viewing of the video, *Can You Lift 100 Kg?* (Lewis, 2000b). The researcher led the teachers in a discussion after each lesson study phase was viewed on the video. Similar to the first lesson study cycle, participants then began by identifying a research theme and engaging in a needs assessment in mathematical content areas. Each school group was then asked to select a content topic to address in their lesson planning. The session ended by each group being assigned a "knowledgeable other," who would facilitate the group throughout the cycle. Although this study did not follow the participants through the second lesson study cycle, the researcher was interested in which classroom mathematics teachers would choose to continue participating in lesson study. Consequently, data collection ended after the second three-hour professional development session in February. For the purpose of the GEAR UP Math Initiative, data was gathered on the lesson cycles for all participating groups.

Overall Timeline

October 16, 2004: First Full-Day Professional Development Session

Early November, 2004: Two-Hour Planning Session

Late November, 2004: Research Lesson Session and Two-Hour Reflection Session

February 8, 2005: Three-Hour Follow-Up Professional Development Session

February 15, 2005: Three-Hour Follow-Up Professional Development Session

Data Collection

The data collection for the current study consisted of qualitative measures.

Qualitative Measures

Nine qualitative measures were used to gather information. These measures included (a) baseline surveys, (b) teacher logs, (c) electronic discussions, (d) planning session transcripts, (e) lesson plans, (f) observation notes, (g) reflection session transcripts, (h) student comments and work, and (i) student assessments.

Baseline surveys. Two baseline surveys were collected on all middle school mathematics teachers who participated in the study. The Teacher Background Information (Appendix B) was divided into four sections: (a) participant description, (b) educational background, (c) teaching experience, and (d) level of GEAR UP involvement.

The second baseline survey was the Mathematics Teacher Survey (Appendix C), modified from Horizons Research, Inc. 2000 National Survey of Science and Mathematics Education Mathematics Teacher Questionnaire. The audience for the instrument is K-12 mathematics teachers. The instrument was developed and administered to a nationally representative sample of mathematics teachers as part of the

2000 National Survey of Science and Mathematics Education and solicited information regarding teachers' opinions, their preparation, and their instructional practice (Horizon Research Inc., 2003).

For the purpose of this study, only the questions pertaining to instructional practices were used in order to provide a baseline related to the teachers' beliefs about instructional strategies in teaching mathematics. The first eight questions addressed teachers' opinions while the following 13 questions pertained to student objectives. The next 11 questions addressed mathematics instruction followed by 18 questions regarding mathematics activities. The survey ended with eight questions pertaining to the frequent use of technology while teaching mathematics.

Teacher logs. Participating teachers were asked to keep a log documenting their lesson study experiences. The log was designed with the purpose of tracking participant involvement. This was done through the charting of the independent and collaborative planning times. (Appendix D)

Electronic discussions. Participating teachers were asked to share their lesson plans, questions, ideas, and strategies through an electronic discussion board using *Black Board,* a web-based software system which is used to support flexible teaching and learning and provides online collaboration and communication (http://www.vuw.ac.nz/home/glossary). The use of *Black Board* was designed with the purpose of tracking dialogue and interactions related to lesson study. From this data, information concerning teachers' beliefs about teaching strategies and mathematical content knowledge was gathered.

Meeting/planning/reflection sessions. All participating teachers met for one six-hour professional development session followed by two 2-hour sessions during the first lesson study cycle. During the initial meeting of the cycle, the researcher and a Master's graduate student in the School of Education at the collaborating private university gathered data by recording observations and comments made by the participants throughout the day. Following the initial six-hour professional development, each participating group of teachers scheduled a two-hour planning session in order to complete their plans for the research lesson. During this two-hour planning session, a Master's graduate student in the School of Education at the collaborating private university or the researcher gathered data by scripting the participants' conversations. All participants met for a second two-hour reflection session following the research lesson. During this two-hour reflection session, a Master's graduate student in the School of Education at the collaborating private university or the researcher gathered data by scripting the participants' observations and comments. In addition, the reflection session was video and/or audio recorded.

Lesson plans. A completed lesson plan was collected from each participating group prior to teaching the research lesson. Lesson plans included: research theme, objectives, lesson sequence, anticipated student responses, lesson summary, assessment, lesson materials, follow-up, and seating charts (Appendix I).

Observation forms. Observation forms were collected from all research lesson observers. The following is a list of observed tasks: whole class statements and questions asked by the teacher; whole class comments and questions asked by the students;

chalkboard, overhead, and *PowerPoint* information; and comments and questions asked by individual students or groups (Lewis, 2002b) (Appendix G).

Student assessments. Data was collected from teacher-made content assessments for the students enrolled in the classes selected to participate in the research lessons. This data was used by the researcher to analyze the effects lesson study had on students' mathematical understanding. In addition, student data was collected from the district's second nine-week benchmark assessment; this data was used to analyze student achievement in mathematics.

Data Analysis

In order to eliminate bias during this study, the researcher served only in the role of recorder throughout the planning, observation, and reflection sessions. It should, however, be noted that during the observation and reflection of the research lesson for one case study, the researcher did serve as the facilitator due to unforeseen circumstances. All recorded data was then transcribed and read multiple times by the researcher. In addition, the transcripts were read and verified by a mathematics specialist in the School of Education at the collaborating local private university. After all transcripts were read and verified by two sources, the researcher began hand coding the data based on broad categories aligned with the research questions. After the researcher had coded the various transcripts, once again a mathematics specialist from the participating local private university independently coded the transcripts in order to help establish validity. The researcher and mathematics specialist then met to discuss and verify the coding as a means to assure accuracy of the findings (Creswell, 2003). The use of a computer software program, a sixth version of non-numerical unstructured data indexing, searching, and theorizing, referred to as N6, was then used to input data points electronically as well as support the coding of the data (Richards, 2002). An open coding approach was used to code the arising categories that emanated from the research questions. Then as patterns emerged from the analysis, axial coding was used to identify subcategories. Axial coding facilitates building connections within categories, both between categories and sub-categories, and thus served to deepen the theoretical framework underpinning the analysis (Fielding & Lee, 1991).

Using the SPSS software (http://www.spss.com), the researcher ran the Wilcoxon Signed Ranks Test in order to determine any significant differences between the pre and post Mathematics Teacher Survey (Appendix C). A significance level of .05 was used. The Wilcoxon was appropriate for this sample because measures were repeated on the sample participants and the sample size was small (Kirk, 1999).

Using the *Edusoft* software, the researcher compared the differences in means across various groups of students. *Edusoft*, a division of Houghton-Mifflin Company, is a web-based assessment platform that tracks student performance across three types of assessments: state exams, district benchmarks, and classroom tests. *Edusoft* automatically grades assessments and gives districts the needed data to evaluate student achievement (http://www.edusoft.com). Therefore, the researcher was able to do a means comparison from the targeted assessment questions, derived from the district nine-week test, related to the research lessons' mathematics topics and skills.

Through the means of the various data sources such as--planning sessions, lesson plans, observation notes, and reflection sessions, the use of pre and post questionnaire data, and student performance--the researcher was able to verify findings through the triangulation of data across multiple sources (Creswell, 2003). Table 4 describes the procedures used in order to analyze the data collected in this study.

Table 4

Research Questions and Data Analysis Summary

Question	Instrument(s)	Data Collection	Analysis
What effects does lesson study have on middle school mathematics teachers' beliefs about instructional practices?	Mathematics Teacher Survey	Pre and Post Survey Observation Notes *Black Board* Lesson Plans Planning Transcripts Reflection Transcripts Videotapes	Descriptive Statistics (N6) Wilcoxon
What effects does lesson study have on middle school mathematics teachers' content knowledge?	NA	Observation Notes *Black Board* Lesson Plans Planning Transcripts Reflection Transcripts Videotapes	Descriptive Statistics (N6) Wilcoxon
What effects does lesson study have on middle school students' mathematical understanding?	Teacher-Made Assessment	Student Work Observation Notes Reflection Transcripts	Descriptive Statistics (N6)
What effects does lesson study have on middle school students' mathematical achievement?	District second nine-week benchmark assessment	Student Work Observation Notes Reflection Transcripts	Descriptive Statistics (N6) *Edusoft*
Does the participation in lesson study as a form of professional development serve as a catalyst for the growth and continuation of lesson study within the middle school mathematics community?	NA	Teacher Log *Black Board* *PowerPoints*	Descriptive Statistics (N6)

Summary of Data Analysis

The first stage of data analysis used descriptive statistics to describe each case study in terms of variables such as gender, ethnicity, and teaching experience. In the second stage, descriptive statistics were used to assess the impact that lesson study had on middle school mathematics teachers' instructional practices and content knowledge by examining each case study. The third stage of data analysis analyzed the differences in means for targeted test-items across the three case studies as well as descriptive statistics to support the impact that lesson study had on students' mathematical understanding and achievement. The fourth stage consisted of a cross-case analysis using descriptive statistics to identify the commonalities in the impact that lesson study had on teachers and students within and across all case studies. In the fifth and final stage, an attempt was made to describe the conditions necessary for the continuation of lesson study.

CHAPTER FOUR

Analysis of Data

Background Information

This study involved an urban school district in central Texas and a local private university in its sixth and final year of a grant awarded nationwide by the United States Department of Education to help disadvantaged students prepare for and gain an avenue to undergraduate programs. In 1998-1999, this urban school district and local private university joined in a partnership to engage middle school mathematics students and teachers in mathematical explorations and investigations as well as support for mathematics instruction which addressed the goals of the nationwide grant, Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP). In an effort to sustain student achievement and understanding in mathematics, as well as developing and supporting exemplary teaching practice, one component of the sixth year goal was to put in place a professional development model focusing on teaching practices and collaborative planning that the mathematics teachers, local schools and the school district could institutionalize and maintain after the current specific funding ended through GEAR UP (Wilkerson, personal communication, September 14, 2004). During the spring of 2004, a focus group, consisting of one mathematics teacher from each of the seven local middle schools was formed to discuss options of professional development formats that would best help them in sustaining effective teaching practices that would positively effect student achievement. After discussion, it was decided that the professional development model that best fit the goals for the sixth and final year for the local GEAR UP funding was lesson study. Lesson study can be defined as a teacher-led instructional improvement cycle in which teachers work collaboratively to: formulate goals for student learning, plan a lesson, teach and/or observe the lesson, reflect on the lesson, revise the lesson for improvement, and re-teach the revised lesson (Perry & Lewis, 2003; Curcio, 2002).

Initial Training on Lesson Study

On October 16, 2004, twenty middle school mathematics teachers, representing all seven middle schools, arrived at the local private university to learn about and engage in lesson study. The agenda for the day can be found in Appendix A. The teachers began by completing a Teacher Background Information Survey (Appendix B) in order to ascertain gender, age, ethnicity, highest degree earned, teaching experience, and level of participation in previous GEAR UP activities. In addition, teachers completed the Mathematics Teacher Survey, (Appendix C) which was modified from Horizons Research, Inc., 2000 National Survey of Science and Mathematics Education Mathematics Teacher Questionnaire for K-12 mathematics teachers. The Mathematics Teacher Survey includes teacher opinions, emphasis on student objectives, frequency of instructional strategies, time allowed for various classroom activities, and use of calculators and computers.

The researcher then asked teachers to think about the students they teach and to identify the qualities they would like their students to have five or more years from now. Teachers were then to independently list their students' current qualities and to compare the ideal and the actual (Lewis, 2000b). During this phase, teachers were grouped by schools. After with-in school comparisons of student qualities, each group was asked to share and discuss their lists with the whole group in order to develop a research theme or a main goal for lesson study. The group research themes are as follows:

- Group A: For students to enhance their desire to learn as they develop their willingness to persevere in working through problems that challenge their thinking.
- Group B: We would like for students to possess the qualities of being logical thinkers and compassionate and productive citizens.
- Group C: For students to apply mathematical principles and basic skills to become productive, responsible individuals.
- Group D: For students to develop effective communication skills and problem-solving skills to be marketable to business and to excel in society.
- Group E: For students to develop motivational techniques that establish relationships, relevancy, and rigor.

After each group developed their research theme, the GEAR UP project director of the Mathematics Initiative, led the next task of analyzing the district and state curriculum expectations for the second nine weeks of school and to identify the needs and strengths at the school level. The rationale for focusing on the second nine weeks curriculum was because this was the targeted time frame to implement the research lesson. Each group was then asked to share their needs and strengths pertaining to topics during the indicated nine weeks in order to examine commonalities and differences. The groups' content needs were as follows:

- Group A: Probability, proportions, and problem solving
- Group B: Measurement, probability, number operations, and algebraic reasoning
- Group C: Number operations and measurement
- Group D: Proportional reasoning, probability, and measurement
- Group E: Ratios and proportions, measurement, number and operations

Based on content needs, teachers were asked to regroup if necessary. Consequently, five groups were formed. Group A consisted of three mathematics teachers and one college Intern from the same middle school. Group B consisted of four mathematics teachers and one administrator from the same middle school. Group C consisted of two mathematics teachers from one middle school and two mathematics teachers from a different middle school. Group D consisted of four mathematics teachers from a middle school and one mathematics teacher from a different middle school. Group E consisted of one mathematics facilitator, an individual who is campus based and not in the classroom, and a mathematics teacher and administrator from a different middle school who later recruited an additional mathematics teacher to join their group.

Once the new groups were formed, group members were asked to identify a specific content topic to address in lesson planning. Group members were also asked to revisit their research theme and determine if their goal was suitable for all members or to modify it if necessary. During this time, each group was randomly assigned a "knowledgeable other" to provide guidance in future tasks as well as assist with content topics. The "knowledgeable others" consisted of two faculty members from the School of Education and one from the Department of Mathematics at the local private university.

After the participating teachers regrouped based on content needs and interests, a consultant for Southwest Educational Development Laboratory (SEDL), provided an overview of Liping Ma's findings from *Knowing and teaching elementary mathematics* (1999). The SEDL consultant discussed Ma's research of a comparative study between American and Chinese elementary mathematics teachers. The findings indicated that Chinese teachers had a strong awareness of the conceptual structure inherent in elementary mathematics and able to teach for conceptual understanding as well. Part of the Chinese teachers' conceptual understanding came from making mathematical connections. Chinese teachers refer to a group of pieces of knowledge rather than a single piece of knowledge (Ma, 1999).

Teachers were then assigned the task of constructing a knowledge package using resources such as district textbooks, curriculum documents, Internet resources, and supplementary instructional resource books. Each group was charged to think of the necessary mathematics concepts and skills that were needed to master the mathematical topic identified, then do the following:

- Decide on the one concept or skill that is most crucial for student mastery of the new concept
- Identify ideas and concepts needed for students to master the specific identified skill
- Identify the NCTM standards
- Identify the grade levels where the connecting or supporting skills are introduced and/or maintained
- Develop a lesson with procedural and conceptual understanding of the mathematics

While each group developed their knowledge package, the researcher was able to capture various conversations as an indicator of teachers' conceptual and procedural understandings. Teachers from Group D had the following conversation pertaining to procedural knowledge:

> Did we put ratio and rate together? I know we put division, did we put multiplication? We said, multiplication, but we may want to identify cross products. Oh, you mean the butterfly. I hate saying the butterfly because that is the first thing the kids do when they multiply fractions. Well, we will just clarify they can only cross multiply with an equal sign.

Group C was thinking deeply about mathematical topics and connections. For example, "What's the difference between a fraction and a ratio and does it matter? A fraction doesn't always represent a ratio, but a ratio can always be a fraction." Groups spent approximately an hour and a half developing and sharing their knowledge packages.

Following the creation of knowledge packages, the GEAR UP project director asked teachers to reflect orally on their impressions and understanding of lesson study based on their reading of Stigler and Hiebert's *The Teaching Gap* (1999). All participating teachers were provided with a copy of *The Teaching Gap* prior to attending the October 16th professional development and asked to specifically read chapter seven, which explained the concept and idea behind lesson study.

The reflection on the *The Teaching Gap* brought about the following comments. "This would be a better way to teach so let's do it now! But unless we start at grade K, it can't happen in middle school. In America, we try to do everything at once; total reform." Another teacher responded, "If it doesn't happen in one year, then we immediately change it." A third teacher weighed in by stating, "My background is elementary, and I teach middle school. We can't blame elementary teachers. Elementary, however, isn't being taught as well because the comfort level is not there." After about a ten minute discussion, the GEAR UP project director concluded with the following statement, "It's not about us becoming like Japan. The question is what can we learn from this? The American goal is to teach something new; Japanese is to teach why. We have things to learn from each other."

The SEDL consultant then provided an overview of the lesson study cycle before teachers viewed a video of a group of Oklahoma teachers in an initial lesson study cycle. After viewing the video, the consultant concluded by pointing out some critical factors in lesson study. "The focus is the lesson itself, the reaction of the students. The focus is not the teacher. Teachers are researchers of the lesson. Lesson study is a process and is linked to our expectations for our kids."

Participating teachers were then introduced to the use of an electronic *Black Board* as a means to support collaboration. *Black Board* is a web-based software system which is used to support flexible teaching and learning and provides online collaboration and communication (http://www.vuw.ac.nz/home/glossary). A Master's graduate student in the School of Education at the collaborating private university demonstrated how to log onto *Black Board*, communicate with group members, retrieve documents, and post documents.

The day ended with each group scheduling their initial lesson planning session with their assigned "knowledgeable other" and completing an evaluation form. The evaluation form consisted of four questions pertaining to the benefits and concerns of lesson study (Appendix E). Each teacher was also given a log to record their time spent planning, reflecting, and participating in lesson study (Appendix D).

Participants

For the purpose of this study, the researcher focused on three out of the five lesson study groups. The three case studies consisted of Group B, Group C, and Group D. These groups were selected based on the number of classroom teachers in each group verses the number of facilitators and administrators since research question one addressed the impact lesson study had on mathematics teachers. For example, Groups B and C consisted of four classroom teachers and Group D consisted of five classroom teachers as compared to Groups A and E which each had three or less classroom teachers. Each of these groups were also assigned a different "knowledgeable other" to facilitate the lesson planning and reflection sessions as well as assist in content knowledge. Demographic characteristics of the 13 participating classroom teachers are reported in Table 5.

Table 5

Teacher Demographics for the Case Studies by Groups

Description	Group B (n = 4)	Group C (n = 4)	Group D (n = 5)
Gender			
Female	3	3	3
Male	1	1	2
Ethnicity			
Caucasian	0	3	4
Hispanic	0	0	1
African-American	4	1	0
Other	0	0	0
Age			
20-29	0	1	2
30-39	0	2	1
40-49	1	1	0
50+	3	0	2
Education			
Bachelors	4	4	4
Masters	0	0	1
Doctorate	0	0	0
Years Teaching			
0-5	1	1	2
6-15	1	2	1
16-25	1	1	1
26-35	1	0	1
Teaching Math			
0-5	1	1	3
6-15	1	2	0
16-25	1	1	1
26-35	1	0	1

Data Analysis

This study used a qualitative approach using a constant comparative analysis involving three case studies. The two stages of analysis consisted of both within and across case comparisons. Once the analysis of each case study was completed, a cross-case analysis was implemented in order to develop more sophisticated descriptions and more powerful explanations (Merriam, 1998). It should also be noted that through the means of the various data sources such as: planning sessions, lesson plans, observation notes, and reflection sessions; the use of pre and post questionnaire data; and student performance, the researcher was able to verify findings through the triangulation of data across the multiple sources (Creswell, 2003).

Prior to the first lesson planning session, the researcher met with each knowledgeable other to explain the procedures and tasks during the planning session (Appendix F). The lesson plan format was also introduced and explained at this time (Appendix I). Meeting with the "knowledgeable others" was essential to having consistency in implementation within the case studies.

Prior to the first research lesson and reflection session, the researcher met with each "knowledgeable other" to explain the items to be addressed before the day of the research lesson and the procedures for the reflection session (Appendix H). The "knowledgeable others" were reminded to verify that the following items had been addressed and completed: lesson plan, invitations for additional observers if applicable, substitute teachers if applicable, time and location for research lesson, permission to videotape the research lesson, and time and location for the reflection session. The researcher reviewed the data to be collected at the end of the reflection session as well. Each "knowledgeable other" collected the following: lesson plan and handouts, seating chart, student work, observation forms, and participation logs. Each participating teacher ended the reflection session by once again completing the Mathematics Teacher Survey (Appendix C).

Throughout the lesson study cycle, the researcher collected notes from planning sessions, lesson plans, observation notes, and recordings from reflection sessions. All recorded data was then transcribed and read numerous times by the researcher. In addition, the transcripts were read and verified by a mathematics specialist in the School of Education at the collaborating local private university. After all transcripts were read and verified by two sources, the researcher began hand coding the data based on broad categories aligned with the research questions. After the researcher had coded the various transcripts, once again a mathematics specialist from the local private university coded the transcripts in order to help establish validity. The researcher then met with the mathematics specialist to verify the coding (Creswell, 2003).

The use of a computer software program, a sixth version of non-numerical unstructured data indexing, searching, and theorizing referred to as N6 was then used to input data points electronically as well as support the coding of the data (Richards, 2002). In order to code the arising categories, an open coding approach was used that emanated the research questions. Then as patterns emerged from the analysis, axial coding was used to identify subcategories. Axial coding facilitates building connections within categories, both between categories and sub-categories, and thus served to deepen the theoretical framework underpinning the analysis (Fielding & Lee, 1991). It should be noted that throughout the transcripts, both the researcher and mathematics specialist noticed numerous comments from teachers regarding student engagement. After a careful analysis of the transcripts, the researcher and mathematics specialist agreed that a third theme emerged in regards to the effects of lesson study on students. The third emerging theme was identified as student engagement. Consequently, the reader will find throughout each of the case studies a discussion on student engagement.

Student engagement in learning has been linked to retention and student achievement (Brewster & Fager, 2000). For this study, student engagement will be defined as the level of students' participation in classroom activities and their disposition towards learning and working with others (Willms, 2003). The emerging theme of student engagement is an important factor because according to Lumsden (1994), by the time students enroll in middle school, lack of interest and engagement in school work becomes increasingly apparent in more and more students. In addition, middle school students' motivation to engage in learning may be influenced by their social group just as much as, if not more than it is by teachers (Mac Iver & Reuman, 1994). Evidence from this study indicates students were engaged as a result of curiosity, interest, and enjoyment in the lesson activity.

After the data was hand coded and verified, the information was entered into the sixth version of non-numerical unstructured data indexing, searching, and theorizing, referred to as N6, software program (Richards, 2000). This software program allowed the researcher to use a constant comparative analysis involving each case study both within and across case comparisons while coding individual documents (Merriam, 1998).

Each participant completed a pre and post Mathematics Teacher Survey (Appendix C). The Survey had 58 items grouped into five categories: teacher opinion, student objectives, mathematics instruction, mathematic activities, and calculators/computers. Using the SPSS software (http://www.spss.com) the researcher ran the Wilcoxon Signed Ranks Test in order to determine any significance between the pre and post Mathematics Teacher Survey (Appendix C). The Wilcoxon was appropriate for this sample because measures were repeated on the same participants and sampling size was small (Kirk, 1999). A significance level of .05 was used.

The results of the Wilcoxon Signed Ranks Test are reported in Tables 6-10. Table 6 shows the results from the eight questions pertaining to teachers' opinions. Table 7 displays the results from the 13 questions addressing student objectives. Table 8 displays the results from the 11 questions pertaining to mathematics instruction. Table 9 displays the results from the 18 questions addressing mathematics activities. Table 10 shows the results from the eight questions addressing the frequent use of technology.

Results of the Wilcoxon Signed Ranks Test indicated that there were significant differences ($p < 0.05$) in the categories of teachers' opinion and mathematics instruction. Teachers' opinions on considering themselves to be a "master" mathematics teacher revealed a significant increase in their pre and post Mathematics Teacher Survey. In addition, results indicated a significant decrease in the level of assigned mathematics homework.

Table 6

Mathematics Teacher Survey
Teachers' Opinions

Questions	$\sum R+$	$\lvert \sum R- \rvert$	T(13)	*p**
a. Students learn mathematics best in classes with students of similar abilities	2.0	8.0	2.0	0.257
b. State /district program dictates the content I teach	12.5	2.5	2.5	0.157
c. I enjoy teaching mathematics	1.0	0.0	0.0	0.317
d. I consider myself a "master" mathematics teacher	15.0	0.0	0.0	0.025*

(table continues)

Questions	∑R+	|∑R-|	T(13)	*p**
e. time to work with colleagues on mathematics curriculum and teaching	16.0	12.0	12.0	0.729
f. Regularly share ideas and materials related to mathematics teaching	14.0	14.0	14.0	1.000
g. Regularly observe other mathematics teachers	9.0	12.0	9.0	0.739
h. Contribute actively in decision making	23.0	5.0	5.0	0.121

$*p < 0.05$

Table 7

Mathematics Teacher Survey
Teachers' Emphasis on Student Objectives

Questions	∑R+	|∑R-|	T(13)	*p**
a. Increase students' interest in mathematics	3.0	0.0	0.0	0.157
b. Learn mathematical concepts	2.0	4.0	2.0	0.564
c. Learn mathematical algorithms/ procedures	9.0	12.0	9.0	0.739
d. Develop students' computational skills	0.0	0.0	0.0	1.000
e. Learn how to solve math problems	0.0	1.0	0.0	0.317
f. Learn how to reason mathematically	2.0	4.0	2.0	0.564
g. Learn how mathematics ideas connect with one another	1.0	0.0	0.0	0.317
h. Prepare for further study in mathematics	12.0	3.0	3.0	0.180
i. Understand the logical structure of mathematics	17.5	10.5	10.5	0.527
j. Learn the history and nature of mathematics	9.0	12.0	9.0	0.739
k. Learn to explain ideas in mathematics effectively	5.0	5.0	5.0	1.000
l. Learn how to apply mathematics in business and industry	6.0	9.0	6.0	0.655
m. Learn to perform computations with speed and accuracy	5.0	5.0	5.0	1.000

$*p < 0.05$

Table 8

Mathematics Teacher Survey
Teachers' Emphasis on Mathematics Instruction

Questions	∑R+	∣∑R-∣	T(13)	*p**
a. Introduce content through formal presentations	8.0	2.0	2.0	0.257
b. Learn mathematical concepts	2.0	4.0	2.0	0.564
c. Engage the whole class in discussion	5.5	15.5	5.5	0.279
d. Require students to explain their reasoning when giving an answer	10.5	10.5	10.5	1.000
e. Ask students to explain concepts to one another	12.5	32.5	12.5	0.212
f. Ask students to consider alternative methods for solutions	9.0	27.0	9.0	0.194
g. Use multiple representations	25.0	30.0	25.0	0.782
h. Allow students to work at their own pace	12.0	16.0	12.0	0.705
i. Help students see connections between mathematics and other disciplines	22.0	33.0	22.0	0.527
j. Assign mathematics homework	0.0	28.0	0.0	0.014*
k. Read and comment on the reflections students have written, e.g., in their journals	6.0	9.0	6.0	0.680

**p ‹ 0.05*

Table 9

Mathematics Teacher Survey
Teachers' Emphasis on Types of Activities

Questions	∑R+	∣∑R-∣	T(13)	*p**
a. Listen and take notes during presentation by teacher	6.0	4.0	4.0	0.705
b. Work in groups	10.0	0.0	0.0	0.059
c. Read from a mathematics textbook	5.0	10.0	5.0	0.480
d. Read non-textbook mathematics-related materials in class	9.5	18.5	9.5	0.438
e. Engage in mathematical activities using concrete materials	4.0	2.0	2.0	0.564
f. Practice routine computations/ algorithms	9.0	12.0	9.0	0.739
g. Review homework assignments	18.0	27.0	18.0	0.564
h. Follow specific instructions in an activity	6.5	8.5	6.5	0.783

(table continues)

Questions	∑R+	|∑R-|	T(13)	*p**
i. Design their *own* activity	10.5	10.5	10.5	1.000
j. Use mathematical concepts to interpret and solve applied problems	6.0	9.0	6.0	0.655
k. Answer textbook or worksheet problems	3.0	12.0	3.0	0.180
l. Record, represent, and/or analyze	24.0	12.0	12.0	0.366
m. Write reflections	9.0	6.0	6.0	0.655
n. Make formal presentations to rest of class	6.0	9.0	6.0	0.655
o. Work on extended mathematics investigations (a week or more)	12.0	3.0	3.0	0.180
p. Use calculators or computers for learning or practicing skills	7.0	14.0	7.0	0.414
q. Use calculators or computers to develop conceptual understanding	1.0	5.0	1.0	0.276
r. Use calculators or computers	6.0	9.0	6.0	0.655

$^*p < 0.05$

Table 10

Mathematics Teacher Survey
Teachers' Emphasis on the Frequent Use of Technology

Questions	∑R+	|∑R-|	T (13)	*p**
a. Do drill and practice	18.0	18.0	18.0	1.000
b. Demonstrate mathematics principles	12.0	9.0	9.0	0.739
c. Play mathematics games	15.5	5.5	5.5	0.279
d. Do simulations	14.0	7.0	7.0	0.414
e. Collect data using sensors/probes	3.0	0.0	0.0	0.157
f. Retrieve or exchange data	10.5	17.5	10.5	0.527
g. Solve problems using simulations	12.0	9.0	9.0	0.739
h. Take a test or quiz	10.0	26.0	10.0	0.248

$^*p < 0.05$

The following discussion will reveal the experiences and impact lesson study had on the participating teachers and students from Case Studies B, C, and D, respectively. Demographics for each case study will be shared. Findings regarding the impact lesson study had on teachers will be supported through an analysis of statements by the participants throughout the planning and reflection sessions as well as the lesson plan for the research lesson. In addition, pre and post test survey question results will be described. Findings regarding the impact lesson study had on students will be supported through an analysis of statements by teachers and students throughout the reflection session as well as students' work from the research lesson. In addition, students' performance results on targeted questions from the district nine weeks assessment will be discussed.

Group One: Case Study B—Madison Middle School

Participants

The following names will be used to represent the four participating teachers from Madison Middle School: Diann, Sally, Vinson, and Kay. The researcher served as the planning session recorder. At no time did the researcher interfere or influence the discussion. Table 11 represents the demographics for the participating teachers in the identified school. Table 12 represents the demographics for the students' in Madison Middle School.

Background for Case Study B—Madison Middle School

From the October 16, 2004 professional development session on lesson study, group members had determined their research theme to be, "We would like for students to possess the qualities of being logical thinkers and compassionate and productive citizens." The content topic was for students to learn to use measurement tools and estimating skills.

Table 11

Case Study B—Madison Middle School
2004-2005 Demographics of Teachers

Description	Case Study B (n=4)
Gender	
Female	3
Male	1
Teacher Ethnicity	
Caucasian	0
Hispanic	0
African-American	4
Age	
20-29	0
30-39	0
40-49	1
50+	3
Years Teaching	
0-5	1
6-15	1
16-25	1
26-35	1

Table 12

Case Study B—Madison Middle School
2004-2005 Demographics of Students

Description	Case Study B (n=310)
Student Ethnicity	
Caucasian	6%
Hispanic	55%
African-American	39%
2005 Passing State Assessment	
6^{th}	32%
7^{th}	32%
8^{th}	36%

On November 1, 2004, four middle school mathematics classroom teachers met with their assigned university faculty member, serving as the “knowledgeable other” to begin the planning for their fall ‘04 research lesson. The first two-hour planning session began by having each teacher share what he/she had done in the past with measurement. The most common strategy used in past lessons was to have students’ measure real life objects in inches and centimeters.

Prior to the November 1, 2004 planning session, Diann had shared a measurement activity with the other group members that she had received from a past workshop. The activity was to sketch a portrait of one’s face based on measuring the different facial features. The group members liked this activity and decided to use the scheduled planning session to modify the activity to meet their objective. So to clarify, the university faculty member serving as the “knowledgeable other” asked, “Students construct the face according to the given measurements, comparing estimates to actual?” After group members confirmed the task, the “knowledgeable other” asked the teachers to think about their research theme and whether or not the lesson addressed their long-term goals. The teachers did think the lesson addressed their goals because the students “have to be productive working on the team” and sensitive by “not making fun of other students.” With the activity selected, the participating teachers began to discuss the details of the lesson.

Vinson volunteered to teach the research lesson to his 8^{th} grade class which had fourteen students. Vinson also volunteered to write the directions for the activity and suggested the lesson be introduced with the following question, “Have you really ever looked at yourself?” Following the question, Vinson would put the state objectives, Texas Essential Knowledge and Skills (TEKS), for the day on the overhead and then explain the activity.

The planning session ended by each individual deciding on an observation focus. Diann would observe the interactions of a particular group of students. Sally said, "I'm interested in what the students are saying," so she decided to observe the conversations of the groups. The "knowledgeable other" would focus on the use of the measurement tools. Kay did not volunteer for an observation focus because she would not be able to attend the research lesson due to a scheduled surgery at that time. Vinson clarified that those who would observe different groups of students should focus on individual student understanding as well as group interaction. In addition, group members determined roles and responsibilities to complete before the day of the research lesson. Vinson was going to continue thinking about the flow of the lesson. Kay and Sally were going to start thinking about and gathering supplies for the research lesson. Diann was going to begin typing the lesson plan. The first planning session ended with the teachers inviting the "knowledgeable other" and the researcher to their mathematics department meeting on November 17, 2004, in order to finalize plans for the research lesson.

On November 17, 2004, the four middle school mathematics classroom teachers met with their assigned university faculty member, serving as the "knowledgeable other" to begin their second planning session. The second planning session occurred during a department meeting so only twenty minutes was allowed for discussion on the upcoming research lesson. The teachers in attendance from Madison Middle School were Diann, Sally, Vinson, and Kay. The researcher served as the planning session recorder. At no time did the researcher interfere or influence the discussions.

The second planning session began by the “knowledgeable other” reviewing a draft of the lesson plan typed by Diann. The “knowledgeable other” pointed out that they needed to add how they would introduce the lesson and explain the details of the activity. In addition, materials such as the students’ recording sheet for their estimates and actual measurements would need to be created. A seating chart needed to be created and attached to the research lesson plan in order for observers to identify particular students. The second planning session ended by Diann and Sally agreeing to finish typing the lesson plan. The complete lesson plan can be found in Appendix J.

On December 1, 2004, Group B delivered their research lesson to a group of eighth grade students. The two-hour reflection session took place that same day immediately after school. Those in attendance for the reflection session included: Vinson, Sally, Diann, and the researcher. It must be noted that Kay was unable to participate in the research lesson and reflection session due to a previously scheduled surgery. The assigned “knowledgeable other” had to leave town the day before the scheduled research lesson, due to a death in the family. Consequently, the researcher had to assume the role of observer during the research lesson as well as facilitate the discussion during the reflection session.

Case Study B: Teachers’ Instructional Practices

Evidence suggests lesson study did impact teachers’ instructional practices in the following two areas: 1) modified instructional activities to encourage more student collaboration and engagement with mathematics and 2) increased the use of concrete materials to promote student understanding.

Modified instructional activities and student grouping. During the first two hour planning session, the participating teachers discussed how students would be grouped and their various roles during the lesson activity. Kay asked, “What sort of groups?” Sally said, “I say three.” Diann said, “I do four.” Teachers then determined that groups of four would work best because each group would have a recorder, a measurer, a drawer, and a timer. The following conversation then occurred:

> Knowledgeable other: Clarify for me, only one student will estimate?
> Diann: Right.
> Knowledgeable other: So if you are the model, do you make the estimate?
> Diann: Yes.
> Vinson: So this is based on them looking in the mirror?
> Diann: No one else can say anything.
> Knowledgeable other: So I estimate myself without touching my face. Do they all draw?
> Sally: The others can help with the directions and also be involved with the measuring.

Based on the previous statements, only one student per group would have the opportunity to practice his/her estimation skills. However, Vinson did question how each student would be assessed if only one individual was responsible for the estimations. Vinson said that in order to assess the students, a comparison between the students' estimates and actual measurements should be the focus. According to Vinson, “I want the students to go back and measure the features and compare the drawing to the actual. Put the estimates and the actual measurements on paper.” Sally asked if every student would receive a worksheet. Diann responded by saying, “I think so. Then everyone will be responsible.”

Therefore, each student would receive a recording sheet; however, the roles for each group member did not change. Only one student was responsible for determining the estimations. According to the final lesson plan, the students would be told, “You will be divided into groups of four. Each group will need a recorder, a person to draw, a measurer, and the person whose face is being drawn."

During the actual research lesson, Vinson, the lead teacher, did not follow the written lesson plan. Instead, Vinson introduced the activity by saying, "We are going to let you use centimeters to draw yourself and then estimate your dimension. You have ten minutes for the estimated part and ten minutes for the other. List estimated measurements on the left side and actual on the right side." During the second planning session, the teachers had decided that the recording sheet would have one column for estimates and a second column for actual measurements. It should be noted, however, that the recording sheet distributed to the students contained only one column.

The reflection session began by Vinson sharing his thoughts about the lesson. Vinson mentioned that he immediately noticed several students did not estimate, but went right to the actual measurement by using the rulers. Consequently, Vinson felt he was forced to bypass the estimates and address actual measurements. The researcher informed Vinson, Diann, and Sally that after placing the TEKS on the overhead Vinson said, "We are going to use centimeters today. We are going to let you use centimeters to draw yourself and then estimate your dimensions." Vinson then showed the students a hand sketched portrait of him before putting up the face directions on the overhead and handing out the worksheet. Vinson then told the students, "You have ten minutes for the estimated part and ten minutes for the other. Estimated measurements should be on the left side and the actual on the right side." Several students, however, immediately started measuring with the rulers. When Vinson noticed this, he told the students, "Get a partner and start measuring each other's face and then you can compare your measurements to the estimates." Sally interjected, "What I would do, once they estimate, I would collect their things and I would have a second sheet and say okay, now you're going to do your actual measurements. Once they do the actual measurement, I would give them back their sheet and let them compare." Vinson then said, "Looking back on it, I would probably withhold those rulers until after the estimation."

The teachers determined that they would modify the follow-up lesson so that more students were able to estimate and measure the actual dimensions of their face by changing the group size and the structure of the activity. Sally said that when the students return, class should begin by asking students what an estimate is. Then a sheet with one column will be given to each student to record the estimates for their partner's facial features. The recording sheet used during the research lesson would serve as the actual measurements since the students didn't estimate but actually measured with the rulers instead. If time allows, students will then draw a portrait using the actual measurements.

The pre and post survey questions from the Mathematics Teacher Survey (Appendix C) support a change in the teachers' beliefs on having students work together. Vinson moved from sometimes (one or twice a month) allowing students to work in groups to all or almost all lessons allowing students to work together. Kay also increased the frequency of students working together from sometimes to often (once or twice a week). Sally and Diann remained the same in often allowing group work and sometimes, respectively.

Hands-on use of concrete materials. During the first two hour planning session, each participating teacher began by sharing what he/she had done in the past when teaching measurement. Diann said, "Last year I asked my students to bring in cereal boxes and all kinds of different things and we measured in centimeters and inches." Sally said, “I have had kid’s measure things from the classroom such as books, doors, and desks.” Vinson said that he, too, had students’ measure objects in the classroom. Kay said she had students “measure different parts of the body.” All teachers indicated that they liked hands-on activities when it came to measurement and they really wanted the students to be able to use a ruler.

Teachers did select a hands-on activity that they thought would interest the students. According to the final lesson plan, Vinson would introduce the lesson by asking the students, “Do you know how you look?” Today we are going to test your knowledge of the metric system by drawing a sketch of your face in centimeters.” The materials listed to be used included: face directions sheet, tape measures, scissors, tape, markers, rulers, and butcher paper.

During the reflection session, Vinson mentioned that the students seemed to like the hands-on activity, but struggled with the measurement tool. According to Vinson, “The students had problems using the rulers. Their heads were very obviously larger or smaller than what they showed.” Vinson went on to say that students had to be able to read a ruler more accurately and to take better measurements; however, Vinson did mention, “I believe they did come out ahead because they became interested in it.”

The pre and post survey questions from the Mathematics Teacher Survey (Appendix C) also support an improvement of instructional strategies. Results indicate the Madison Middle School mathematics teachers increased their use of concrete materials. Both Sally and Diann went from sometimes (once or twice a month) allowing the use of concrete materials to often (once or twice a week) while Vinson and Kay remained the same in their use of engaging in mathematics through concrete materials.

According to Hart (2000), the use of manipulative and hands-on activities is critical for students' comprehension of middle school mathematics. The middle school years are the times in which students' transition from the concrete to the abstract. Consequently, middle school students must be allowed the use of concrete materials to help them succeed with this transition.

Case Study B: Teachers' Content Knowledge

Based on teachers' comments throughout the planning and reflection sessions, the lesson plan, and the pre and post Mathematics Teacher Survey (Appendix C), there appeared to be a lack of content knowledge. Evidence suggests lack of teachers' mathematics content knowledge in the following two areas: 1) teachers did not focus on the purpose of the lesson and 2) teachers focused on the activity and not the content knowledge.

Lack of focus on lesson objective. During the planning session, the teachers had a discussion on whether students should measure in inches, centimeters, or both. Sally made the comment, "It hurts me when they can't count the little lines in a ruler." Kay said, "It's a lot easier to measure in metric." Sally then suggested the students could use both units of measurement, "We have centimeters and inches on either side. It is easy to just flip over." Vinson commented that he would like very precise measurements using millimeters instead of centimeters. With such debate on which unit of measurement to use, it begs the question of whether or not the teachers understood the appropriateness of the different units and the purpose of the activity. According to the lesson plan, the lesson objective was, "For students to develop estimation skills in measurement using something they see everyday." However, the participating teachers discussed the accuracy of students' measurements instead of estimation skills.

Second, teachers were unclear on how to assess whether or not students mastered the objective for the lesson and consequently focused more on the students' artistic abilities instead of the mathematics. During the planning session, Kay suggested students be assessed based on the accuracy of their measurements. "If the nose is 30 centimeters, then they are wrong." Sally said their measurements could "maybe be off two to three centimeters." The "knowledgeable other" said, "With a nose, that's a lot." Sally then suggested just a participation grade. According to the lesson plan, however, students were to be assessed by arranging their circumference measurements from their heads in ascending order. It should be noted that students were given a ruler instead of a tape measure to determine the circumference of their heads and at no time did the participating teachers question the appropriateness of a ruler.

During the research lesson, the class period ended before students were able to determine all of their facial measurements so did not place their head measurements in ascending order as planned on the lesson. Consequently, during the reflection session, how to assess the students was once again discussed. According to Vinson, "A competition could be formed of who could draw the best; make the better features and so forth. Who's drawing came out the best." Based on the teacher's comment, his focus does not appear to be on mathematical content but rather on art and the ability to draw. Kay and Sally did like the idea of pairing students up, but ultimately did not determine how they would assess students' understanding. Once again, evidence suggests the teachers missed the purpose of the lesson.

Activity instead of content. Throughout the reflection session, teachers were not able to articulate content observations. Instead, the observations noted by the teachers related to the activity. For example, Sally recorded observations such as, "They (the students) changed the estimated amount when the actual was measured." Sally also noted only questions the students asked aloud such as, "Can we write on the sheet? Can we fold the paper?" In addition, Diann only recorded the four following observations:

- Student drew a graph
- Measure directions from paper
- Place dimension from paper
- Talking across the room

As a result of these observations, teachers were unable to discuss their own content understanding because the focus was either on the procedures of the activity or the behavior of the students.

According to the pre and post Mathematics Teacher Survey (Appendix C), the objective of learning to explain ideas in mathematics effectively resulted in a decrease. Both Sally and Diann went from a heavy emphasis to a moderate emphasis on the importance of explaining mathematical ideas effectively. Vinson and Kay had no change; however, did decrease in the importance of understanding the logical structure in mathematics. Vinson went from a heavy emphasis to a minimal emphasis in understanding the logical structure of mathematics. Kay went from a heavy emphasis to a moderate emphasis. The participants decrease in logical understanding and explanation of mathematical ideas seem to support a lack of understanding in content knowledge.

Conclusion on Effects on Teachers

Based on the prior descriptive statistics and statements, evidence suggests lesson study did have an impact on the Madison Middle School mathematics teachers' instructional strategies, but not their content knowledge. Vinson, Diann, and Sally improved their instructional strategies by making the following changes to their research lesson:

- Have students estimate the facial features of their assigned partner
- Collect the paper with the estimates
- Distribute rulers and have students measure the facial features of their assigned partner
- Return estimates so students can compare
- Extend to a two-day lesson so teacher can allow more time for questions and student responses
- Continue to estimate and measure real-life objects such as facial features

All participating teachers agreed that by pairing students up instead of grouping by fours, all students would be actively engaged in estimating and determining the actual measurements. In addition, by having students estimate the facial dimensions on a separate sheet of paper and collecting that paper prior to distributing rulers for the actual measurements along with the second recording sheet would encourage all students to engage in the activity. Finally, the continued use of concrete objects and hands-on activities was viewed as essential by all participants.

Unfortunately, the participating teachers' content knowledge in mathematics did not increase. Vinson, Diann, and Sally lost focus of the purpose of the lesson which was for students to develop estimation and measurement skills. Instead, the participating teachers debated on how students would be assessed. Possible assessments ranged from students' measuring their head circumference (with an inappropriate measurement tool) to the best drawing. Participants focused on the procedures of the activity instead of content understanding which ultimately resulted in a lack of content articulation. In order for teachers to help students make mathematical connections and communicate their mathematical understanding and ideas, teachers themselves must have deep content knowledge (National Research Council, 2001a; Smith, 2001; Ma, 1999).

Background Review for Case Study B—Madison Middle School

In order to select a topic, the participating teachers analyzed the state mathematics curriculum, Texas Essential Knowledge and Skills (TEKS), for the second nine weeks of the school year. Based on the groups analysis of the skills taught during the second nine weeks, estimation was determined to be a weak area. Even though the use of a ruler and how to perform basic measurements was not specifically addressed in the TEKS, the teachers knew their eighth grade students struggled not only with estimation but finding actual measurements as well. Therefore, the objective of the research lesson was, "For students to develop estimation skills in measurement using something they see everyday." The everyday item to be used was the students' faces. Fourteen eighth grade students were to sketch their portrait before using a ruler to measure their actual facial features. Students were to estimate the following areas:

- Height of face (distance between chin and top of forehead)
- Width of face
- Height of forehead
- Height of ears
- Width of one eye (from corner to corner)

- Distance across the bridge of nose (from inside corner of one eye to inside corner of the other eye)
- Length of nose
- Distance between the tip of chin and bottom of smile
- Width of smile (outer edge to outer edge)
- Distance around the top of head (where a hat would fit)

Case Study B: Students' Content Understanding

Evidence suggests lesson study did not impact students' conceptual understanding in mathematics. Based on statements from participating teachers during the reflection session and an analysis of students' work, evidence indicates students' lack of understanding in the following three areas: 1) meaning of estimate, 2) mathematics interest, and 3) use of measurement tools.

Lack of estimate understanding. During the reflection session, Vinson, the lead teacher said, "I've been with the students over a period of time, but they do have a problem; difficulty with measurement and this lesson." Vinson went on to say that he noticed many of the students apparently thought they did not achieve appropriate estimates because they bypassed that and moved on into actual measurements. Vinson informed the observers that the students didn't have an understanding or idea of the different unit lengths. According to Vinson, "This class doesn't quite get that the width of the pinky is about a centimeter."

Sally said that one of her two groups did estimate their facial features; however, "They chose to erase what they had predicted and put down what they had actually measured." Sally also stated that she didn't think the students understood how to measure or estimate their facial features. According to Sally, one student asked, "Which way do I measure the distance around my face? Do I go North, South, East or West?" Sally also said, "I didn't see Josh estimate in the beginning, all he did was the actual measurement. I think that's why his scale was so small because I'm not sure he understood the directions." Sally suggested to Vinson that he should be more precise in the directions in order to help students in their understanding. Sally suggested, "I think maybe if you (referring to Vinson) had come back and said don't erase because you want to compare between the two, I think they would have not erased."

According to the researcher, two students in group four started measuring with their rulers before they estimated, and one student started estimating; however, she then quickly measured her estimated feature and noticed it was not exact and erased the estimate. The researcher said, "She was the only one who made that one estimate, measured it, saw it was off, erased it, and started doing the actual. She and the other two never did another estimate." The researcher then posed the question of whether or not the teachers thought their students understood the concept of estimation. The teachers did indicate that they thought the students knew what it meant to estimate and the problems were connected to the directions.

The researcher then shared with the others a strategy used by the two girls in the group. The girls will be referred to as Kim and Mia. According to the researcher, "Mia held the ruler up to her eye, but didn't let the ruler touch it, and then asked Kim, 'What's my eye?' holding the ruler right there." The researcher went on to comment that she was unable to see whether Mia recorded the measurement as the exact or estimate. The researcher stated, "I'm curious to see if just by holding it up and eyeballing it from one person to the next if that is the way they were estimating or if they really considered that to be the exact measurement." When the students' papers were viewed, it was inconclusive as to whether the dimensions were estimates or actual measurements as a result of having only one column on the recording sheet.

Students focused on art instead of mathematics. Based on several recorded statements from the students, evidence seems to indicate that students were more focused on their artistic abilities than their understanding of mathematics. For example, Kim asked the teacher, “How can we draw our face?” Then proceeded to say, “I don’t know how you measured that. I can just draw myself.” The researcher shared that Kim then drew a small sketch in the corner of her paper in order to see if she could actually draw her face. Another student, John, would look at the self portrait the teacher had drawn as an example and then draw his features. Meanwhile, Kim made another comment, “I can’t do this. I need to take an art class.”

The research lesson concluded by having students display their facial drawings so that others could assess the accuracy of the portraits. Vinson began the discussion by asking, “Look at Josh’s face. Just looking at the drawing, does this look like Josh?” One student commented, “His hair.” It should be noted that students were not required to estimate the length of their hair particles which indicates students were focused on their ability to draw and not measure. According to the researcher, during the discussion, three students simply started drawing their portraits. The students did not use a ruler and seemed to concentrate simply on their artistic abilities.

Lack of understanding with measurement tools. The students’ use of the measurement tools was also an indicator for students’ lack of understanding. For instance, Kim admitted, “I used the wrong side of the ruler.” A few moments later, Kim pointed out to Mia, “You are doing the wrong side. He said centimeters.” The researcher informed the teachers that Kim and Mia would sometimes say inches while other times they would say centimeters. The researcher went on to indicate that she thought the girls were thinking in the customary unit even though they may have had the correct side of the ruler revealed. Vinson said, "I also noticed they possibly have a problem with even using the ruler. Some of them in measuring their heads were very obviously larger or smaller than what they showed."

Students' work indicates lack of understanding. Students' work was randomly selected in order to examine student understanding of estimation and actual measurements. Table 13 shows students' work for some of the randomly indicated facial features.

Table 13

Madison Middle School Sample Student Work Results

Student	Facial Feature	Estimate	Actual
Angel	Height of ears	4 cm	6.5 cm
Josh	Distance around head	14 cm	60.3 cm
Karen	Height of forehead	5 cm	2 cm
Daniel	Height of face	18 cm	8 cm
Yamily	Width of face	10 cm	19 cm
Richard	Length of nose	2.5 cm	4.5 cm

Based on the above student data, it appears Josh, Richard, and Yamily do not have a clear understanding of what it means to estimate or they do not understand the approximate length of a centimeter. For example, the distance around the top of your head was defined by the teacher as "where a hat would fit;" therefore, Josh's estimate of 14 centimeters indicates a lack of reasonableness and ability to estimate. Richard's estimate of 2.5 centimeters for the length of his nose also indicates a lack of understanding in the meaning of an estimate. The width of your face was defined by the teacher as the "distance from ear to ear." Consequently, Yamily's estimate of ten centimeters is not reasonable and clearly indicates either a lack of understanding in estimates or the length of a centimeter.

In viewing the actual measurements of the students' facial features, the evidence indicates a lack of understanding for a couple of students. Karen and Daniel do not have reasonable or accurate measurements for their forehead height and face height, respectively. Karen's measurement of two centimeters for her forehead height indicates both a lack of reasonableness in measurement as well as the lack of ability to measure using a ruler. Daniel's measurement of eight centimeters for his facial height also indicates a lack of understanding in measurement.

Case Study B: Students' Achievement in Mathematics

For this case study, a means comparison of students' performance on the participating school district's nine week assessment was not applicable. The topic selected by the Madison Middle School teachers was based more on fundamental basic needs instead of a particular area to be assessed on the nine week district assessment. Consequently an analysis of the exam revealed no test items addressed the skills of estimate and actual measurements.

Case Study B: Students' Engagement in Mathematics

Based on the teachers' comments throughout the reflection session, evidence suggests there was an impact on students' engagement. Sally admitted that she had been concerned about the behavior of a particular student. The student will be referred to as David. David, however, was highly engaged in the activity. Vinson agreed that David was very responsive. According to Vinson, "I like the way all students responded and acted towards the activity, and I have had positive comments from them already." Sally added that she had complimented David when she had him for the following period and according to Sally, "It just changed David's attitude because he has been on a roll." Diann agreed that David's engagement had changed his whole outlook in class.

Diann also mentioned that she was shocked to see another student who normally does not participate in class become completely involved in the research lesson activity. The student will be referred to as Jason. Diann said, "I was totally shocked with Jason." Sally answered, "With Jason, yeah; actually thinking; actually working." Diann added, "Jason is a hands-on person." Sally summarized that students did achieve because they were all engaged in the activity. According to Sally, "The students gave much better than what I expected."

Conclusion on Effects on Students

Based on the prior descriptive statements and students' work, lesson study did not have an impact on students' conceptual understanding and mathematics achievement. Lesson study did, however, impact students' engagement.

Throughout the planning and reflection sessions, teachers indicated that students lacked conceptual understanding of reasonable measurements as well as lacked an ability to use measurement tools effectively. According to Kay, "They (students) can't imagine a foot." Vinson added that these students also struggled with the idea that a centimeter is about the width of the pinky. Sally also commented, "They (the students) can't read a ruler."

Based on the analysis of the randomly selected students' work and the statements made by the participating teachers, evidence suggests that students did not understand the concept of measurement. However, it should be noted that certain factors beyond the student's control may have influenced the lack of conceptual understanding. For example, during the research lesson, students were given the wrong recording sheets. The recording sheet given to the students only had one column to write in measurements instead of one column for estimates and a second column for actual measurements as originally discussed in the planning session. Secondly, students were limited in their use of measurement tools. The students were required to measure the distance around the top of their heads; however, they were only provided a ruler and not a tape measure. Consequently, the accuracy of their measurements could have been affected.

Unfortunately, there were no means to assess students' achievement in mathematics due to the selected content topic. There was, however, supporting evidence for an increase in student engagement. According to the Madison Middle School mathematics teachers, students who rarely participated in class were actively engaged in the research lesson.

Group Two: Case Study C—Greenville Middle School

Participants

The following names will be used to represent the teachers from Greenville Middle School, Randy and Rachel, and from Highland Middle School, Ashton and

Gladys. A Master's graduate student in the School of Education at the collaborating private university served as the planning session recorder. Table 14 represents the demographics for the participating teachers in the identified school. Table 15 represents the demographics for the students in Greenville Middle School.

Table 14

Case Study C—Greenville Middle School
2004-2005 Demographics of Teachers

Description	Case Study C (n = 4)
Gender	
Female	3
Male	1
Teacher Ethnicity	
Caucasian	3
Hispanic	0
African-American	1
Age	
20-29	1
30-39	2
40-49	1
50+	0
Years Teaching	
0-5	1
6-15	2
16-25	1
26-35	0

Background for Case Study C—Greenville Middle School

From the October 16, 2004, professional development session on lesson study, group members had determined their research theme to be, "For students to apply mathematical principles and basic skills to become productive, responsible individuals." The content topic was for students to develop proportional reasoning skills.

Table 15

Case Study C—Greenville Middle School
2004-2005 Demographics of Students

Description	Case Study C (n = 437)
Student Ethnicity	
Caucasian	12%
Hispanic	55%
African-American	33%
2005 Passing State Assessment	
6^{th}	44%
7^{th}	40%
8^{th}	79%

On October 26, 2004, four middle school mathematics classroom teachers met with their assigned "knowledgeable other" to begin the planning for their fall '04 research lesson. The two-hour planning session began by having each teacher share what he/she had done in the past to focus on proportional reasoning. Gladys mentioned that she had taught a lesson using paperclip chains to measure items in order to determine whether or not the items were proportionate. The lesson came from the *Activities Integrating Mathematics and Science* (AIMS) resource book on proportional reasoning (AIMS, 2000). Gladys explained that students would measure objects using both standard and jumbo paperclips and then graph the relationship between the two sizes of paperclips by plotting points. The graphs should indicate an increase at a constant rate. Rachel commented that she, too, had used the AIMS lesson with her students. Therefore, the group decided to use the paperclip lesson and began to discuss the details of the lesson.

Randy volunteered to teach the lesson to his seventh graders and said that this fourth period class was a little longer than the other periods because of the lunch hour and he had 24 students in that class. The teachers decided to teach the research lesson to Randy's fourth period seventh grade class and form eight collaborative groups of three.

The group then discussed how the lesson would be introduced and decided Randy would begin the activity by posing questions about proportional relationships. The teachers also planned to have different objects, representing the same ratios, for students to measure. In addition, students would represent the measurement comparisons by plotting points on large graphs which would be displayed on the wall.

The planning session ended by each group member deciding on an observation focus for the research lesson. Ashton said that she would observe student questions throughout the lesson. Rachel said, "I will record the questions asked by the teacher." The "knowledgeable other" and Gladys decided to each observe the interactions of a particular group of students. Gladys volunteered to finish typing the lesson plan. The complete lesson plan can be found in Appendix K.

On November 16, 2004, Group C delivered their research lesson to a group of seventh graders. The two-hour reflection session took place that same day immediately after school. Those in attendance for the reflection session included: Randy, Rachel, Ashton, Gladys, and the "knowledgeable other." The "knowledgeable other" also served as the facilitator. The researcher served as the reflection session recorder. At no time did the researcher interfere or influence the discussion.

Case Study C: Teachers' Instructional Practices

Evidence suggests lesson study did impact teachers' instructional practices in the following three areas: 1) encourage a more discovery approach, 2) focus on conceptual understanding, and 3) use real-life situations and materials.

Encourage a more discovery approach. During the planning session, the teachers discussed how the lesson would be introduced. Rachel encouraged the group to let the students "Just jump into it. Your questions will guide their thinking." According to the lesson plan, however, the lesson was introduced by posing questions about proportional reasoning related to comparing Shaq's height/shoe size relationship to a child's height/shoe size.

During the reflection session, Randy began by reminding the group that this was his fourth time to teach the research lesson since he had taught it to his first three periods as well. Randy then shared his thoughts about the instructional approach to the research lesson. According to Randy,

> I hadn't had that much time to sit and think about it, but I almost think it needs to be a two period activity because I had to kind of lead them in the direction I wanted them to go because doing it three other periods this morning, I knew we were going to run out of time if I didn't somehow at least bring up the unit ratio.

Randy went on to explain that when he first taught the lesson, he had just turned the students loose with the task and they didn't get through the first part. Gladys expressed her agreement by stating, "I think if you spread it out over two days you could do Part A then Part B and let it be more discovery."

Taylor reminded the group that her observation focus was to record the questions asked by the teacher and indicated that Randy did indeed ask probing questions. According to Rachel, Randy asked probing questions such as, "How many small paperclips does it take to make two jumbo clips?" Randy also asked, "What does a proportional graph look like? What patterns do you see in this chart?" Rachel reminded the group that Randy then showed the students the graph that made a straight line. Rachel then told Randy that, "Towards the end of the lesson, you started on the questions we had put into the lesson." The planned questions were, "What patterns do you see in the chart? How many times bigger is the standard clip number than the big clip number? How do the patterns you found in the chart show up on the graph?" Rachel also indicated that Randy, however, did not ask two of the planned questions that encouraged students to think at a higher level. For example, one question was, "How could you use the patterns to determine the length of something in standard clips if you know its length in jumbo clips?"

The pre and post survey questions from the Mathematics Teacher Survey (Appendix C) also support the teachers' interest in having students discover ideas and engage in more investigative activities. For example, teachers increased the frequency of designing their own activities or investigations. Gladys and Ashton went from rarely (a few times a year) designing classroom investigations to sometimes (once or twice a month). Randy and Rachel remained the same in their frequency of designing activities or investigations. Randy stayed at sometimes and Rachel remained at often.

Focus on conceptual understanding instead of procedural. During the reflection session, the participating teachers viewed the students' activity sheets and noticed that some of the dimensions for the measured items did not calculate to a 1.5 rate. Every student, however, had recorded a rate of 1.5 for every item measured. This caused the teachers to analyze their instructional approach which led to a discussion on the strategies that would promote conceptual understanding. Gladys commented, "I think this gives us new questions to ask; new ways to see old lessons." Gladys continued to say, "I think that one way the kids would have caught their measuring mistakes in their charts is if instead of just putting 1.5 all the way down, and just assuming that was going to be the rate, actually getting them to divide each one of those to see." The "knowledgeable other" commented that he, too, wondered what would happen if students did all of the measuring first and then looked for a pattern. Randy agreed that maybe the relationship between the paperclips should take place after students have seen that they measure eight and twelve.

The pre and post survey questions from the Mathematics Teacher Survey (Appendix C) support the teachers' desire to have their students comprehend the mathematical ideas and not just the procedures. For example, teachers increased having students explain their reasoning behind their answers. Ashton and Randy went from often (once or twice a week) having students explain their answers to all or almost all lessons. Gladys and Rachel remained the same on their frequency of having students explain their reasoning to answers. In addition, NCTM (2000) says that students should be able to communicate and represent their mathematical ideas.

Use of real-life situations and materials. During the planning session, the group began by discussing how the topic of proportional reasoning would be introduced. Ashton said, "I think the first connection is seeing the rate of the change between things. I think being able to connect it to real-world situations is important." Rachel said, "We could throw in the model of the room; lay carpet on the floor." Randy asked, "Could you have them just measure the paperclip and switch to a more real-life situation?" Gladys suggested, "A football field; paces versus yards, or centimeters to hand; could measure objects using a hand ratio proportion." The group decided to use two sizes of paperclips to measure objects.

Ashton then commented that each group could have different real-life objects to measure, but they would end up being the same size. According to the lesson plan, half the groups would measure the following objects: a marker, a cardboard box, a workbook, a trash can, a hacksaw, and a scale. The other half of the students would measure objects such as: an envelope, a plastic tub, a wallpaper brush, a keyboard, a tire iron, and a television. The group members also decided to have students graph their measurement comparisons on a large graph displayed on the wall. Randy commented, “It wouldn’t be another worksheet.” The teachers agreed that the students would enjoy the use of real-life objects and representing their work on large graphs instead of the traditional worksheets.

During the reflection session, Randy commented, “The hardest part for me was actually trying to find paperclips that worked.” Upon hearing Randy’s statement, the “knowledgeable other” said,

> A thought that occurred to me during the lesson was, is there something that might work better than paperclips? And of course, I thought of more traditional manipulatives like different size interlocking cubes and even *Cuisenaire* rods. But if you use more traditional manipulatives, would you remove some of that interest that seemed to be sparked with we’re gonna do math with paperclips?

Overall, the teachers seemed pleased with the use of real-life manipulatives and the large wall graphs. In fact, the pre and post Mathematics Teachers Survey (Appendix C) results indicate that Gladys and Ashton increased in their use of having students record, represent and/or analyze data. Gladys and Ashton went from sometimes (once or twice a month) having students gather and assess data to all or almost all lessons to often (once or twice a week) respectively and according to NCTM (2000), students should understand symbolism in mathematics and visual aids such as charts, graphs, and diagrams.

Case Study C: Teachers' Content Knowledge

Based on teachers' comments throughout the planning and reflection sessions, the lesson plan, and the pre and post Mathematics Teacher Survey (Appendix C), there appeared to be a positive impact on content knowledge in the following two areas: 1) making mathematical connections and 2) encouraging a discovery approach. It should be noted, however, that evidence also indicated teachers' lack of confidence in their content knowledge.

Making mathematical connections. During the planning session, teachers focused on making connections within and among mathematical topics as well as connecting to real world situations. Gladys commented, "I think being able to connect the topic to real world situations is important." Rachel suggested, "We could throw in a model of a room." Ashton interjected, "Or a blueprint." Gladys mentioned having the students think in terms of football, "Paces versus yards." Gladys also mentioned that the topic could extend into science by teaching the metric system.

In addition to having students see the connection between the mathematical topics and real world situations, the teachers wanted students to see the connections within the concepts as well. Based on the lesson plan, students would measure objects, determine the rate of small paperclips per large paperclips, graph the relationships, and make predictions based on a constant rate. Not only did teachers want students to understand mathematical connections, but they worked to increase their own understandings. For instance, during the initial planning, the participating teachers discussed their conceptual understanding of the selected content topic. For example, Randy asked, "What is the difference between a fraction and a ratio and does it matter?"

Students need to be able to make connections within and among mathematical ideas as well as connect to real world and to other disciplines. Teachers must have a deep content knowledge in order to help students make mathematical connections (Ma, 1999; Ball, 1990; Hill, Rowan, & Ball, 2005).

Based on the pre and post Mathematics Teacher Survey (Appendix C), results indicated all four teachers consistently put a heavy emphasis on the importance of knowing how mathematics ideas connected with one another. The survey, however, indicated in the area of helping students see connections between mathematics and other disciplines there was a slight decrease in emphasis. Gladys and Ashton continued to make mathematical connections in all or almost all lessons. Randy dropped from all or almost all lessons to often (once or twice a week). In addition, Rachel dropped from often helping students see connections between mathematics and other disciplines to sometimes (once or twice a month). In conclusion, the participating teachers continued to see the importance of making connections within mathematics' topics, but decreased in connecting mathematics to other fields of study.

Encouraging a discovery approach. During the reflection session, teachers determined the lesson should be taught over two days so that students could spend more time discovering the proportional relationships. According to Randy, "I wish I had a little longer. I almost think it needs to be a two period activity because I had to kind of lead them in the direction I wanted them to go." Gladys agreed and said, "I think if you spread it out over two days, you could do Part A and Part B and let it be more discovery." According to Thompson (1984), teachers' instructional practices were related to their knowledge of mathematics. Teachers with deeper content knowledge encouraged students to discover mathematical relationships as well as make predications and communicate their reasoning.

Lack of confidence in content knowledge. It should be noted that the teachers made comments that indicated a lack of security in their content knowledge. For instance, Randy commented that the first time he looked at the activity, "I didn't understand it. I guess I was just going to jump into measuring items instead of actually measuring the paperclips themselves." Rachel also commented, "I couldn't figure it out and I was embarrassed." Gladys then said, "I always say to figure it out for bonus." In addition, when the "knowledgeable other" asked the teachers what they would like for him to focus on during the research lesson observations, Gladys said, "Why don't you see if they (the students) are getting it since you are the math professor." It should also be noted that the "knowledgeable other" did not think the participating teachers strengthened their content knowledge or focused on content as much as they should. The "knowledgeable other" made the following comment to the researcher after all teachers left the first planning session, "We were looking for a good lesson instead of thinking about mathematics." Interestingly enough, after the reflection session and the group had completed their first lesson study, the "knowledgeable other" wrote the following to the researcher,

> I was disappointed in the content discussions with this group. We focused on finding a lesson for proportional reasoning and the lesson we chose seemed not to be 'content-revealing' concerning ideas in proportional reasoning.

Conclusion on Effects on Teachers

Based on the prior descriptive statistics and statements, evidence suggests lesson study did have an impact on the teachers' instructional strategies as well as their content knowledge. Randy, Rachel, Ashton, and Gladys improved their instructional strategies by implementing the following changes to their research lesson:

- Extend to a two-day lesson
- Better preparation in the distribution of materials
- Questions that are less guided and allow for more student discovery
- Focus on rate prior to graphing
- Continue to use a real-life manipulative such as a paperclip

All participating teachers agreed that by extending the lesson to two days, students would have time to discover the proportional relationships and ultimately increase their conceptual understanding. In addition, by having students focus on rate prior to graphing, conceptual understanding would increase. Finally, all teachers agreed that the use of real-life manipulatives and objects resulted in capturing students' interest.

Evidence suggests participating teachers' content knowledge improved as a result of making mathematical connections between topics such as measurement, proportions, rate, and graphing. In addition, teachers became more aware of the abilities of their students to make such connections. During the reflection session, Gladys commented, "I think the whole slope idea didn't have to be brought in, but leave it at unit rate." Ashton said, "It's hard as a teacher because we see the connections, but do we overload and confuse the students?" Teachers also agreed to extend the lesson to two days so students could have time to process the ideas and take a discovery approach in order to deepen their understandings. In order for teachers to help students discover mathematical connections, teachers themselves must have deep content knowledge (Perry, Lewis, & Akiba, 2002; Ma, 1999; Thompson, 1984).

Background Review of Case Study C—Greenville Middle School

In order to select a topic, the participating teachers analyzed the state mathematics curriculum, Texas Essential Knowledge and Skills (TEKS), for the second nine weeks of the school year. Based on the groups analysis of the skills, proportional reasoning was a weak area. Therefore, the group members decided to address the following skills: use ratios to describe proportional situations, use ratios to predict proportional situations, and use division to find unit rates and ratios in proportional relationships. More specifically, the objectives for the research lesson were as follows:

- Students will use two different sized paperclips to measure objects.
- Students will see the relationship between the large and small paperclips and determine the rate of small paperclips per large paperclips.
- Students will graph the relationship between the two sizes of paperclips by plotting points.
- Students will observe that the graph increases at a constant rate, and will be able to predict further lengths.

Students were assigned to groups of three and were responsible for three tasks. First students were to determine how many small paperclips were needed to be equivalent to two large paperclips and to do the same with 4, 6, 8, 10, and 12 large paperclips. Second, each group had six specific real-life objects that were to be measured using large and small paperclips. Finally, students were to graph their results on the coordinate plane.

Case Study C: Student Content Understanding

Evidence suggests lesson study did impact students' conceptual understanding in mathematics. Based on statements from participating teachers during the reflection session and an analysis of students' work, evidence indicates students' understanding in the following four areas: 1) the meaning of proportions, 2) the procedures of graphing, 3) the meaning of constant rate, and 4) peer collaboration and tutoring.

Meaning of proportions. During the reflection session, Rachel informed Randy and the others, "I think the students accomplished the task. I think they understood what proportions meant as well as writing a ratio, and they understood going from a large object to a small one." Gladys agreed with Rachel in that the students really seemed to understand proportions. According to Gladys, "I could tell that the kids knew a lot about proportions before they started, just comparing to when I taught my kids; your kids caught on." Ashton also indicated that she seemed to think that most students understood the concept of the relationship and whether or not something was proportional.

The procedures of graphing. During the reflection session, Gladys commented that she had observed group two and she noticed the lack of confidence in some students. Gladys said, "Mary was starting to graph all her points, and she was really worried that they were wrong. Olivia, however, helped her graph her points so they all got the same thing. They were really good at plotting points." Gladys then stated that she noticed group one had some confusion with the graphing. Gladys mentioned,

> It seemed like they really never grasped the aspect of plotting the points. I also noticed that Mary had a hard time understanding the rate to find a large number. She kept thinking she divides by the rate instead of multiply by the rate.

Gladys went on to explain that as students looked at the big graph, they seemed to have a hard time if it was not exactly in a straight line. Gladys concluded by saying, "If one little sticky note was off, just a little bit, then they thought theirs didn't have the same rate." Gladys thought, however, that this indicated that students did have an understanding of the meaning of a constant rate.

Meaning of constant rate. During the reflection session, Ashton reminded the group that she had observed student questions and statements. Ashton said that during the review, at the beginning of class, there were about four students that seemed to answer most of Randy's questions, and one student in particular seemed too dominate. According to Ashton, "Ebony seemed to raise her hand on almost every single question and tended to have an answer and a good response to all the questions." Rachel agreed that Ebony was quick to see a pattern during the beginning review. Rachel said, "Students pretty much caught on that they were adding three each time and that the constant rate was three over two and then Ebony said 1.5."

Peer collaboration and tutoring. During the reflection session, Ashton commented that it was easy to figure out the leaders in the groups. Ashton said that she noticed the students would check each other's work and the leader in the groups would always make the corrections. For instance, Ashton said, "The leader would check and basically comment, 'No, you're not counting enough, you need to go up'."

Ashton mentioned that she thought overall the students really understood the concept. For example, Ashton said that group four not only worked well together but even found and corrected their own mistakes. According to Ashton,

> After plotting their points, group four looked at it and all points were straight except for one, and that happened to be the 11:17 ratio. So they looked between the 11 and the 17 and said, "Oh, 16.5 would probably be a better answer," so they were basically correcting themselves.

The "knowledgeable other" interjected that his group had a similar discussion. According to the "knowledgeable other", "I think they were talking about the tire iron. It really measured 11 big to 16.5 small paperclips. My group had a discussion, but they went ahead and decided to round it. They at least had that discussion about whether to use 16.5." Ashton said that she also recorded a very interesting conversation between the girl and one of the boys in group four. Ashton said the conversation went as follows:

> Girl: You've got four and four to six
> Boy: Oh we're following a pattern!
> Girl: No, you've got to understand this. This is what's happening – you multiply by 1.5.
> Boy: There's a pattern!

Ashton concluded by saying that she heard a lot of knowledgeable comments from students as they were graphing their points. Ashton said, "Lots of conversations about whether it's a straight line; correcting each other if their thought was not the correct thought; checking their work; students looking and comparing." Ashton said that she even noticed students would pull their papers together and say, "Something's wrong here, you need to go back and look at it."

The "knowledgeable other" said that his particular group of students also had a very interesting conversation that revealed their conceptual thinking. The students first got an envelope and had a discussion about what was width. Jose, one of the students, disagreed with his other group members about which dimension represented width, but finally Jose was convinced that the taller side was the width. The "knowledgeable other" commented that he wanted to say "Jose, I'm with you." The "knowledgeable other" went on to say that he really wanted to tell the students that it really didn't matter.

Students' work indicates conceptual understanding. Part A of the assigned activity had students determine how many small paperclips would be equivalent to 2, 4, 6, 8, 10, and 12 large paperclips. Table 16 represents Part A which established students' understanding of a constant rate and proportional reasoning.

Table 16

Greenville Middle School
Actual Example of Students' Worksheet-Part A

Number of Large Paperclip	Number of Small Paperclip	Ratio of Small to Large Paperclips
2	3	1.5
4	6	1.5
6	9	1.5
8	12	1.5
10	15	1.5
12	18	1.5

In analyzing students' work for Part A, it should be noted that 100 percent of the students completed the table correctly. All students recorded the small paperclips to be 3, 6, 9, 12, 15, and 18 respectively. In addition, each student calculated the rate of small paperclips for each large paperclip to be 1.5.

Part B of this activity consisted of having students' measure real-life items with small and large paperclips. All students' work was analyzed for randomly selected objects to measure in order to show student understanding. Table 17 represents Part B of the student worksheet. Data indicates different students counted different amounts of large and small paperclips for each randomly selected object. What is most interesting is that every student recorded every rate of small to large paperclips to be 1.5. Even with the discrepancy in the students' rate calculations, the evidence is not conclusive that there is a lack of understanding. The participating teachers seemed to think the difference was more a result of estimating or rounding. Rachel observed one group who, "Came across a problem that their paperclip chain was too small, and a student used his fingers to estimate how much longer." Randy agreed, "The students estimated the measurements instead of getting the exact."

Table 17

Greenville Middle School
Representation of Students' Worksheet-Part B

Object	Number of Students	Number of Sm. Paperclips	Number of Lg. Paperclips	Small to Lg.
Envelope	4	6	3	1.5
	5	8	7	1.5
	5	7	3	1.5
	5	7.5	1	1.5
Tube	6	9	7	1.5
	6.5	10	1	1.5
	7	10	1	1.5
	8	10	1	1.5
Marker	3	5	2	1.5
	3	6	3	1.5
	3	4.5	4	1.5
Keyboard	10	15	6	1.5
	11	16	3	1.5
	6	11	3	1.5
	11	15	2	1.5

Case Study C: Students' Achievement in Mathematics

Evidence suggests lesson study did impact student achievement in mathematics. Based on a means comparison on students' performance on the district nine week assessment, evidence suggests there was student achievement.

Student test performance. The indicated TEKS to be addressed during a particular time interval are evaluated by a district assessment at the end of each nine week grading period. In order to determine student achievement for the selected mathematics topic, the researcher ran a means comparison of students' performance on the district assessment based on the questions addressing only the appropriate TEKS taught during the research lesson. The software used to analyze student achievement on the assessment questions related to the research lessons' TEKS was *Edusoft*. *Edusoft*, a division of Houghton-Mifflin Company, is a web-based assessment platform that tracks student performance across three types of assessments: state exams, district benchmarks, and classroom tests. *Edusoft* automatically grades assessments and gives districts the needed data to evaluate student achievement (http://www.edusoft.com).

An analysis of the district seventh grade exam revealed four questions addressed patterns and proportional relationships. Table 18 reveals the percentage of students who answered the four questions correctly from Randy's fourth period academic class (who participated in the research lesson), all seventh grade academic classes taught by Randy, and all seventh grade academic classes in the district. It should be noted that Randy taught the research lesson not only to his fourth period class but to all of his academic classes. Randy's first period class was an Athens class (advanced) while the remaining classes were academic (regular). Therefore, the percentages shown in Table 18 do not include Randy's first period class.

As previously mentioned, Randy taught the research lesson to all of his academic classes; therefore, comparing Randy's academic classes to all 7th grade academic classes in the district are entirely appropriate. Based on the following data, Randy's fourth period class did not out perform the overall percentages of the district. Results from three out of four questions were lower than the district percentages. Randy's academic classes as a whole, however, outperformed all 7th grade academic students within the district. Overall, the evidence supports student achievement on the targeted content area.

Table 18

Greenville Middle School
Students' Achievement on Second NineWeeks District Assessment

Assessment Question	4th Period (% correct)	Academic Classes (% correct)	District Academic (%correct)
Question 3	59%	70%	60%
Question 6	59%	82%	74%
Question 8	55%	65%	60%
Question 29	100%	98%	91%

Case Study C: Students' Engagement in Mathematics

Based on comments by the teachers and the "knowledgeable other" during the reflection session, evidence suggests there was an impact on students' engagement in mathematics. The first thing teachers noticed was the interest students showed because of the use of paperclips. According to the "knowledgeable other," "Something as simple as paperclips made the students interested in the lesson." Randy also commented, "I think the students were more on task today than they normally are." Gladys agreed that the students really were engaged and stayed on task. According to Gladys, "The students seemed to understand it very well, and when one of them was a little confused and the other one would get them right back on track." Rachel said that she noticed how well the group members worked together. "One would measure with the large paperclips and another would measure with the small paperclips. The third group member would record the data." Randy even made note that Randall, usually very lethargic, took on the role of materials collector and was very much engaged in the activity. Overall, the participating teachers felt the students were successfully engaged in the research lesson.

Conclusion on Effects on Students

Based on the prior descriptive statements, statistics, and students' work, lesson study did positively impact students' conceptual understanding, achievement, and engagement in mathematics. Throughout the observations and reflection sessions, teachers indicated that students did have a conceptual understanding of rate and proportional reasoning. According to Randy, "It seemed that the students understood the rate concept and this lesson connected the graph aspect with the rate aspect." Ashton agreed with Randy and stated, "Students were counting from the last point to plot the next point. They understood rate." Rachel also agreed and commented, "Just by looking at their graphs, they knew if they did something wrong." Therefore, based on the analysis of the students' work and the statements made by the participating teachers, evidence suggests that students did understand the concept of rates and graphing.

Based on the teachers' comments and analysis of the district nine week assessment, evidence suggested there was student achievement. Student achievement was supported by a means comparison of students' percentages from the district assessment. In addition, comments by the participating teachers supported an increase in students' engagement in mathematics. According to research, students who are actively learning, meaning students are engaged, will enhance their knowledge and skills (Garet et al., 2001).

Group Three: Case Study D—Patton Middle School

Participants

The following names will be used to represent the teachers from Patton Middle School: Charles, Taylor, Allison, and Evan. Lauren, a teacher from Eastland Middle School, represented the fifth teacher for Case Study D. The researcher served as the planning session recorder. At no time did the researcher interfere or influence the discussions. Table 19 represents the demographics for the participating teachers in the identified school. Table 20 represents the demographics for the participating students in Patton Middle School.

Table 19

Case Study D—Patton Middle School
2004-2005 Demographics of Teachers

Description	Case Study D (n = 5)
Gender	
Female	3
Male	2
Teacher Ethnicity	
Caucasian	4
Hispanic	1
African-American	0
Age	
20-29	2
30-39	1
40-49	0
50+	2
Years Teaching	
0-5	2
6-15	1
16-25	1
26-35	1

Table 20

Case Study D—Patton Middle School
2004-2005 Demographics of Students

Description	Case Study D (n = 461)
Student Ethnicity	
Caucasian	30%
Hispanic	36%
African-American	33%
2005 Passing State Assessment	
6^{th}	65%
7^{th}	62%
8^{th}	32%

Background for Case Study D—Patton Middle School

From the October 16, 2004, professional development session on lesson study, group members had determined their research theme to be, "For students to develop effective communication skills and problem-solving skills to be marketable to businesses and to excel in society." The content topic was to introduce students to proportions.

On October 25, 2004, four middle school mathematics classroom teachers from Patton Middle School met with their assigned university faculty member, serving as the "knowledgeable other" to begin planning for their fall '04 research lesson. The group consisted of five teachers; however, the one teacher from a different middle school who joined this group of four based on the content topic was absent for the first planning session.

The first two-hour planning session began by having each teacher share what he/she had done in the past with proportions. The common activity was to take a cartoon picture and enlarge it. Taylor said, "I personally haven't done a scale factor in the sixth grade. We just have to set proportions up. Scale factor is seventh and eighth grades, but not sixth." The group concluded that the scale drawing was good but not for sixth grade. Prior to the planning session, Taylor, the sixth grade mathematics teacher had volunteered to teach the research lesson.

Charles reminded the group, "What we are supposed to do is more student led." Taylor agreed, "Yes, it needs to be student led." The group members then began to brainstorm about other activities that were more student led. Charles asked the group, "Do we want them to know scale factor or proportions?" After Charles referred to the state curriculum objectives, Texas Essential Knowledge Skills (TEKS), and it was determined that scale factor was not sixth grade mathematics.

Evan, who was a first year teacher, suggested using the human body for proportionality. Evan said, "What if a monster came into the class, how big was the monster?" Evan explained that students could use a proportion of their hand to their height and then measure the paw to determine the monster height (AIMS, 1995). The group members agreed to the idea and thought the activity addressed just what was expected of sixth graders.

After the activity was decided upon, the group began to think about the details of the lesson such as the grouping of students. Taylor volunteered to teach her seventh period class and to have the students form seven groups of three. Allison really liked the idea of three to a group and commented, "One is measuring, one is recording, and one is like being the feet."

The planning session concluded by each teacher deciding on an observation focus and a list of additional people to invite to observe the research lesson. The group members decided to invite the mathematics facilitator for the school district, Janice, and the principal and vice-principal of the school hosting the research lesson. The group also determined that Lauren, the fifth teacher from the other campus, would observe and record the teacher's comments and questions while all other observers would record comments and questions from specific student groups.

The teachers decided that they would need to meet on November 1, 2004, for a second planning session. The teachers also determined their assignments in order to prepare for their next meeting and the research lesson. Charles was in charge of getting pictures from *Monster, Inc.* and incorporating technology. Allison volunteered to make the monsters' paws and Evan was going to think of a creative story to introduce the activity as well as type the lesson plan.

On November 1, 2004, the five mathematics classroom teachers had planned to meet to finalize plans for their research lesson. The "knowledgeable other" and the researcher were unable to attend this planning session, but Charles recorded the meeting so that the data could be gathered. It should also be noted that Lauren, from Eastland Middle School, did not arrive at the meeting until the last five minutes.

The second planning session began with Allison telling the others that she had taught the lesson to her gifted and talented students. Allison explained that she had her students imagine they were going for a walk in a forest and they came upon huge giant prints and their task was to determine how tall the giants were based on the prints that were displayed throughout the room. The other group members liked the use of a story to hook the students' attention and agreed to have Charles continue with this work on a *PowerPoint* using *Monsters, Inc.* Charles did, however, mention that he was a little concerned about using Mike Kazowski, a character from *Monsters, Inc*., because he was a short monster with big feet. The others didn't think this would cause a problem since the *PowerPoint* was just to hook the students' interest and explain the task.

The group then discussed what materials would be needed and what they would expect the students to be able to do in order to assess their mathematical understanding. Allison said students would need, "Butcher paper, a paw print, and a roll of masking tape." After confirming the materials, Taylor stated, "What I expect out of them (the students) at the end is to be able to tell me or be able to mark on the floor rather than tell me the approximate height of their monster." Allison agreed and Evan mentioned, "They should be able to tell you how they got it." Taylor agreed, "Yes, an explanation of your group's plan; the more details the better." Charles suggested that the groups report to the class, which was agreeable to the teachers. Therefore the plan for the lesson consisted of: *PowerPoint* with a clip from *Monsters, Inc.* to introduce the lesson; use of butcher paper, tape, and paw print to figure the height of the monster; an explanation on how the monster's height was determined; and comparison of the heights of the monsters. The complete lesson plan can be found in Appendix L.

On November 18, 2004, Group D delivered their research lesson to a group of sixth graders. The two-hour reflection session took place that same day immediately following the lesson. Those in attendance for the reflection session included: Charles, Taylor, Evan, Allison, Lauren, the principal, the vice-principal, the district mathematics facilitator, and the "knowledgeable other" who also served as the facilitator. The researcher served as the reflection session recorder. At no time did the researcher interfere or influence the discussion.

Case Study D: Teachers' Instructional Practices

The reflection session began by the "knowledgeable other" asking the participating teachers to provide brief background information on the lesson planning so that the invited guest observers would understand the rationale behind the activity.

Therefore, Evan explained that the idea for the lesson came from his experience with an AIMS activity entitled *Hands on Giant* (AIMS, 1995). Allison also shared how she had first taught the lesson to her gifted and talented sixth grade class in order to identify weaknesses and strengths in the lesson. Allison stated, “I saw what the questions were that the kids asked, and some points we needed to cover.”

Evidence suggests lesson study did impact teachers’ instructional practices in the following four areas: 1) level of questioning, 2) analysis of instructional materials, 3) connecting to prior knowledge, and 4) instructional changes.

Level of questioning. During the reflection session, Taylor mentioned that once she noticed students were struggling, she tried to lead them in making the connection between the size of the foot and the height without directly telling the students how to solve the problem. Taylor said she asked one group, “Okay, well does the size of your foot have something to do with how tall you are? My foot’s bigger than your foot, and I’m taller than you are.” Lauren commented that Taylor had asked the students questions such as, “Does the size of your foot have anything to do with how tall you are? Could you make a ratio of your foot to that foot?” The mathematics specialist from the district, who will be identified as Janice, also informed Taylor that her comments and questions really made the students think. For example, Janice had said that in closing the lesson,

> I like the way that after you got all the papers lined up in order, then you said, “Okay, now let’s look at the feet and let’s see if the feet are in order,” and that made a lot of kids stop and look. It really did. They were like, “Oh, that’s right, there has to be a connection between the size of the foot and the height of the paper.”

The pre and post survey questions from the Mathematics Teacher Survey (Appendix C) also supported teachers encouraging students to think by having them use multiple representations to express their thoughts and strategies. Results indicated

Charles went from rarely (a few times a year) having students present their mathematical understandings in multiple ways to sometimes (once or twice a month). Evan, Taylor, and Lauren increased their frequency of multiple representations from sometimes (once or twice a month) to often (once or twice a week). Allison remained at often having students use multiple representations.

Analysis of instructional materials. During the reflection session, group members analyzed factors that influenced students' understandings. Evan commented, "What confused my group was the video because that little monster had big feet and that really threw them off." Taylor said, "You know you're right. In two different groups, I said, 'Do you think the size of your foot makes a difference in how tall you are?' and in those two groups, they both said, 'No, because he had big feet and he was short.' " Charles said that the length of the butcher paper was what confused his group. According to Charles, "My group never got past the length of paper, 'That must be how tall the monster is.'" Charles suggested that in the future, students should have to tear off their own length of paper in order to remove that particular aspect.

Taylor nodded her head in agreement and said, "The whole time you were talking, I was thinking about how I could do this again with a different group, and I can't manage that many pieces of big, huge butcher paper, but I can manage those roles of adding tape." Charles liked the idea of using adding tape. He commented, "Adding tape will be better because it takes the height of the paper out because then again, they are having to measure it."

Allison said her group was confused because they thought the color of the print was connected to the video. According to Allison, "To them it was like if it's blue, he's big, and it it's green, he's small." Allison commented that when making the prints, the colors were selected simply because they coordinated and the connection to the video never occurred to her. Charles also suggested using bigger prints in the future. Charles said, “We think of monsters as bigger, and we had these little bitty feet that weren’t much bigger then theirs.”

Connecting to prior knowledge. Allison expressed her opinion that if students were able to make connections to their prior knowledge, they may have been able to make the connection between the foot size and height much easier. Allison suggested preparing the student’s more on using unconventional measurement prior to the lesson. Taylor said, “That was one of the questions I was going to ask. How could I have prepared them better for this? Use paperclips to measure their math books, do some different things.” Taylor continued to say, “I even tried to bring up the fact that yesterday we worked a lot on the missing number and figuring out what the missing number was. That’s what I call it, the missing number in the proportions.”

The pre and post survey questions from the Mathematics Teacher Survey (Appendix C) indicated an improvement in teachers’ frequency to connect new learning to students’ prior knowledge. Survey results indicate that teachers modified their instruction to help students see connections between mathematics and other disciplines. Both Charles and Allison went from sometimes (once or twice a month) making mathematical connections to often (once or twice a week) where as Taylor went from sometimes to all or almost all lessons.

In order to promote understanding, students must be able to make connections. Whether students are able to comprehend ideas and concepts as a result of connecting new knowledge to prior knowledge or making connections between mathematics and other disciplines teachers must assist students in the challenge of making such connections (National Research Council, 2000, Smith, 2001).

Modified instructional changes. During the reflection session, participants discussed changes necessary in improving the research lesson. The group did like the lesson for an introduction to proportions. According to Charles, “I know that they didn’t make the connection, but I really think that as an introductory lesson, I think it was pretty good.” Janice suggested removing the video as an introduction and let the students use more of their imaginations. She also said, that by having the students’ visualize they would have “less variables to worry about.” The principal, Paige, suggested,

> You might give some kind of an introduction, instead of having monsters in the introduction, have a co-variety of footprints in the introduction with nothing attached to them. You know, the studying of the old magnifying glass looking at different kinds of footprints so that they start thinking in terms of the footprints themselves and not the monster attached to it.

The group discussion ended with suggestions and plans for the next day follow-up as well as changes to make when re-teaching the lesson. Taylor said, “Well, tomorrow what I’ll do is I’ll have them sit with their groups, so they can talk to each other if they need to, so they can refresh what they said, and we’ll go from the different ideas and I’ll lead them into yes, it does matter how big your foot is and how tall your are.” And for future changes, the “knowledgeable other” said, “Changing the paper to using the adding paper,” and Taylor added, “And not giving them a set size of paper.” Evan reminded the group, “and changing the introduction of the lesson by just having mysterious foot prints.” Allison said, “The instructions were good, just different pictures.” The “knowledgeable other” concluded,

> And the procedure we used to present this lesson with the groups discussing the problem and attempting to solve it – we decided that was good, and the three members of the group – we approved that also. So, I think we have really looked

> at making the improvements to this lesson. We've liked it, and we've seen a lot of good things from it, and we've seen the little things we might want to correct.

Case Study D: Teachers' Content Knowledge

Based on teachers' comments throughout the planning and reflection sessions, the lesson plan, and pre and post Mathematics Teacher Survey (Appendix C), there appeared to be an impact on teachers' content knowledge in the following ways: 1) focusing on a lesson topic and approach and 2) collaborating with other teachers.

Focusing on lesson topic and approach. During the first planning session, teachers discussed various activities and approaches to teaching proportions. The teachers decided in order to guide their instructional approach; they needed to review their research theme. The "knowledgeable other" reminded the teachers that their theme was, "For students to develop effective communications skills and problem-solving skills to be marketable to business and to excel in society." Consequently, the teachers agreed that the lesson had to be student led. Charles then asked, "Will they discover or is it just an activity?"

According to researchers, teachers such as Charles, who distinguish between an activity and a discovery, have a true understanding of the NCTM standards. In addition, teachers who encourage students to discover the concepts and strategies in mathematics must have a deep knowledge of subject matter (Ma, 1999; Germain-McCarthy, 2001; Thompson, 1984).

After a lengthy discussion, the teachers decided students would understand the building of proportions from ratios through the use of unconventional measurement. Charles commented, "Lesson study forced me to deepen my content knowledge because in order to truly narrow down our topic, we had to thoroughly understand that topic."

During the second planning session, Allison commented that the monsters' feet were simply made and not in proportion. Charles, however, said, "If they were proportional, we could have the students graph the size of their foot to their height and then that way they could predict what the next one would be." Charles continued to say, "We could tell the students that this is feet per age. You know this is a one year old giant, this is a two year old giant; how tall would they be?" After some discussion, the teachers decided to work with approximately and not necessarily have the monsters' feet in proportion. According to Taylor, "Math will not be the issue; it will be the problem-solving." Charles agreed and later commented, "Trying to think like the students would think during the lesson made me have to look at the lesson as if I was learning it for the first time."

During the reflection session, the discussion focused on the introduction of the lesson and the problem-solving strategies explored by the students as well as the students' conceptual understanding. All participants agreed that students' understanding of mathematics concepts was extremely important and the results of the Mathematics Teacher Survey (Appendix C) support this observation. Based on the survey results, Taylor went from sometimes (once or twice a month) focusing on conceptual understanding to often (once or twice a week). Charles, Evan, Allison, and Lauren consistently stayed at often. After the reflection session, the "knowledgeable other" also supported the teachers' desire for students to have greater conceptual understanding through the means of problem-solving. According to the "knowledgeable other," "The teachers in their discussion after the lesson presentation seemed to agree that more opportunities needed to be provided for students to work in groups on a problem-solving activity."

Collaborating with other teachers. During the first planning session, the participating teachers originally thought about having the students do a scale factor to learn about proportions; however, Taylor said, "I personally have not done a scale factor in the sixth grade. Sixth grade students are only expected to set-up proportions. Scale factor is seventh and eighth grade elements, but not sixth." Charles clarified by stating, "Well, scale factor is just touched on in seventh." It should be noted that later during the study, Taylor was asked if she thought lesson study had deepened her content knowledge. Taylor responded by saying, "The lesson itself didn't deepen my content knowledge, but I do admit that having seventh and eighth grade teachers in the planning did help me see the vertical planning of ratios and proportions through the middle school years."

As indicated by researchers, teachers increase their content knowledge by collaborating on lesson plans and reflecting on instructional strategies (Kwakman, 2003; Phillip, 2003; Guskey, 2000). Perry, Lewis, & Akiba (2002) also indicated in their studies that teachers, who participated in lesson study, strengthened their content knowledge by discussing the flow and continuity of lesson topics and procedures.

Conclusion on Effects on Teachers

Based on the prior descriptive statistics and statements, evidence suggests lesson study did have an impact on the participating teachers' instructional strategies and their content knowledge. Charles, Taylor, Evan, Allison, and Lauren determined the instructional strategies to be changed when teaching the lesson again would be as follows:

- Have students use their imaginations instead of the *Monster's Inc. video* for the introduction
- Use adding machine tape instead of butcher paper

- Allow students to experience measuring items with non-customary units prior to the introductory lesson to proportions

Based on the comments sited from the planning and reflection sessions, lesson study did help teachers strengthen their instructional knowledge. According to Charles,

> Lesson study made me more aware of my own teaching practices. I think that it was great to see "behind the scenes" of what the lead teacher saw. I was able to take a step away from my normal role and view the lesson as an outsider and was able to see the teaching of the lesson in a different light. It is great, also, to see someone else's teaching styles because it makes you critique your own which allows you to improve. As a teacher, anytime I see someone else teach, immediately compare and contrast what they are doing with what I would do the same or differently; therefore, it causes me to self-evaluate and make changes that better my classroom.

Stigler and Hiebert (1999) indicated a need for teachers to collaborate in their instructional planning and to observe colleagues teaching as a means to improve instructional strategies. Taylor supported Stigler and Hiebert's suggestion by stating, "Every lesson I teach enables me to develop and strengthen my instructional knowledge. Lesson study opened up a dialogue with peers, and I thoroughly enjoyed having adults in the classrooms."

Patton and Eastland Middle School mathematics teachers' content knowledge did improve as a result of seeing the importance of allowing students to discover the concept of proportions. Perry, Lewis, and Akiba (2002) indicated in their studies that by encouraging students to discover mathematical concepts, teachers' conceptual knowledge increased as well. As a result of planning a lesson that encouraged students to problem-solve and explore their thoughts and ideas, teachers were able to deepen their own conceptual understandings. According to the "knowledgeable other,"

> Subject matter knowledge was deepened. Through the development of a problem for the students to solve, the teachers discussed what information would the students need to know about proportions in order to solve the problem. Because of the different ways that the problem might be solved it was necessary to identify

> the possible ways such that the teachers' subject-matter knowledge was strengthened.

In addition, teachers increased their content knowledge by understanding the vertical alignment as a result of collaborating with colleagues from different grade levels.

Background Review of Case Study D—Patton Middle School

In order to select a topic, the participating teachers analyzed the state mathematics curriculum, Texas Essential Knowledge and Skills (TEKS), for the second nine weeks of the school year. Based on the groups' analysis of the skills, proportional reasoning was a weak area. Therefore, the group members decided the goal for the research lesson would be:

- For students to understand the building of proportions from ratios
- To have students use unconventional tools of measurement

Students were assigned to groups of three or four and watched a brief *PowerPoint* introducing students to a story involving monsters. Students were then challenged to find the height of a monster based only on a given footprint. Students were also provided a sheet of butcher paper to represent their monster's determined height. At the end of the lesson, students were to arrange their monster heights from the shortest to the tallest.

Case Study D: Students' Content Understanding

Based on statements from participating teachers during the reflection session and an analysis of students' work, evidence indicates the majority of students were unable to understand the concept of proportions based on two areas: 1) lack of cognitive direction and 2) factors that influenced students' confusion. On the other hand, some observers argued that students did understand the concept of proportions and the objective to introduce students to the idea of proportions was accomplished. Therefore, evidence suggests lesson study did have a limited impact on students' conceptual understanding in mathematics.

Students' cognitive direction. Taylor began the reflection session by saying, "I was afraid they (the student) would get stuck. When I went around and asked them what their plan was, they didn't have one. Some of them had a plan, it was just wild." The math specialist for the district, Janice, interjected, "Erin made a couple of really good observations, but then didn't know what to do with it." Allison agreed and stated,

> He said, "Hey, my foot's the same size as this monster's foot, so he must be the same height," but when nobody said anything and the other boys were not interested in what he was talking about, they kind of giggled it off because they had no clue. Erin was then like maybe I'm wrong; I must not be smart enough to know this.

Janice added, "Yeah, because then Malcolm came back and said, 'It's not about our height. It's about the monster's height." Taylor said, "I even went around and tried to lead them by saying, 'Does the size of your foot have something to do with how tall you are?' and half the time they said no."

The principal, Paige disagreed and thought the students were on track. According to Paige, "My group tried their foot against the monster's foot and then there were questions like, 'How tall are you?' They were making those connections at the beginning." Paige went on to explain that the students then got a little side-tracked by discussing the width of the foot and what they could use to measure. Paige concluded, "I think given more time, they might have gotten back into it because they started off pretty strong. They had some good ideas, but they got stuck with how to measure it."

Charles commented that his group of students had no clue on how to compare feet to height. According to Charles, "They took their foot, and their foot went up the paper eight times, so within 30 seconds, they were done. The monster was eight feet tall."

Charles even stated that his group would stop and look at other groups and just as he thought his group was going to generate an idea, from seeing others laying down measuring, the students would say, “Look at those idiots up there.”

Allison thought her group was on target or at least one of the students, Aaron made several enlightened comments such as 12 inches equals one foot which indicated his understanding that measurement had something to do with it. In fact, Aaron said, “The monster’s foot is the same size as mine, so he’s the same height as me.” Unfortunately, the other group members did not agree so Aaron was thrown off track. Allison said, “I think with a little more encouragement, Aaron would not necessarily have gotten the proportional ratio, but he would have gotten the relationship between the foot size and height.

The “knowledgeable other” said that her group was unable to make the connection, but they were really exploring. For instance, the group tried measuring their hands with the monster’s foot but one student said, “No, hands don’t have anything to do with it. It’s feet; it not hands.” So the group then went back and measured their feet to see how many feet they would have all the way down the butcher paper. The “knowledgeable other” said, “They were like, there has to be a connection between the size of the foot and the height of the paper.”

Paige really thought her group was making the connection to the ratio. The following conversation between Paige and Charles support that initial understanding did occur for some students.

> Paige: Dakota said that the monster’s foot was this much bigger than his, and he was five feet tall, so the monster must be this much bigger.
> Charles: But you know what, they’re making that ratio instead of saying.
> Paige: They were.
> Charles: He must be that much bigger than me. At least they were expanding it to say it had to be this much.

> Paige: And they did. I don't know how they came up with their expansion.
> Charles: They did have something going there.

The conversation then moved toward the closing of the lesson when students were asked to bring their foot print and place their butcher paper, representing the height of their monster, from the shortest to the tallest. Allison said that her group of students started looking at the other groups' foot print and paper length and said, "Well our foot's almost the same size as that foot, so let's fold our paper right there." Allison said, "Obviously they (the students) must have understood that if the foot's about the same size, then the height has to be about the same size, so that's how they decided where to fold the paper." Charles said that his group of students thought the given length of butcher paper was the height of the monster and they never got past that thought. Charles said, "As a matter of fact, at the end when we were lining them all up, they had their paper folded back, but they saw they weren't the longest, so they just unfolded their paper to the length of the paper so they were the longest."

After listening to students' actions during the height comparisons, Paige once again stated, "You know, in every group there were comments that the kids were at least looking at the connection. They were saying, 'We gotta have this to compare to this,' and they were trying to find those comparisons." Charles, however, disagreed by stating, "Not my group. It wasn't until Taylor came around, then their ratio was their foot to the monster's foot. There was no mention to going back to the problem and looking at the height; they never made that leap." Taylor added, "When they were telling me it didn't matter who had bigger feet, I thought this is not good." Paige then said,

> I'm thinking back over what they (the students) were doing, and a lot of what they were doing they would get caught up in the structure of it. It was like when they got down to deciding how big the monster's foot was, they reverted back to ruler and pencil and the big picture disappeared. They tried that and then this, but the idea that you need a way to measure, that it was important to know how big it

> was, not just in relation to something else in and of itself, and that's where the relationship part quit because they had no way to decide how big that foot was.

Factors that influenced students' confusion. Evan said that his group was confused because of the video from the *PowerPoint.* Taylor interjected by saying, "That's right. In two different groups I said, 'Do you think the size of your foot makes a difference in how tall you are?' and in two different groups, they both said, 'No because the monster in the video had big feet and he was short.'" Paige said that the groups on her side of the room never commented on the video, but what seemed to have limited them was the fact that they never got around to measuring themselves. Allison commented that she thought the video did hinder the students' understanding. According to Allison,

> As cute as it was, it seems like the monsters were the things that were confusing them. They seemed to think "My foot's blue, and the monster's blue." To them it was like if it's blue, he's big, and if it's green he's small.

Allison continued to say that the group of students she had observed even stated, "It's blue, so it must be big." As the discussion continued, Paige again commented that her group did not mention the video, but questioned whether the concept of monster narrowed the focus in the sense that monsters were always big. Even though some students appeared to be confused as a result of the video and limited guidance from the teacher, others seem to make appropriate connections which supports various study findings that students' content understanding increases when they are allowed to construct their own knowledge (Garet et al., 2001; Wiske, 1998).

Students' work indicates conceptual understanding for some. Participating students were divided into six collaborative groups and asked to write down their strategy in determining their monster's height. Group 1 stated, "We laid down on the paper and measured how tall we were. Malcolm was the tallest so we measured Malcolm's foot, and after we measured his foot, we measured the monster's foot." Group 2 stated, "We decided two monster's feet for the shins, two feet for the upper leg, three feet for the body, one for the neck, and one for the head. He was nine monster feet tall." Group 3 said, "We put Dakota's foot on the paper and talked about how tall we were. We drew a line from the toe to the end of the paper, and we measured about seven and a half feet." According to Group 4, "We studied the foot and came up with thirteen and a half." Group 5 said, "We compared our feet to the foot print. We also measured by 12 inches. We multiplied eight by one thinking it is eight feet tall." According to Group 6, "First we compared our foot to the monster's foot. Then we put the monster foot on the big piece of paper. Next we put our foot on the big piece of paper. Then we laid down on the paper to see what size we were to compare it to our foot size. Then when we put the big foot to our size and compared the big foot the same way we compared our foot to our size. We ended up with 11 feet and 3 inches."

Based on the above comments and procedures, evidence suggests that while most students did not seem to make the connection between foot size and height, some students were able to make the appropriate connection. The students' explanations also support the conclusion of the observers in that students' conceptual understanding cannot be generalized for the whole class but was individualized.

Case Study D: Students' Achievement in Mathematics

Based on a means comparison on students' performance on the district's nine week assessment, evidence suggests lesson study had a limited impact on student achievement in mathematics. The reader should be reminded that this particular research lesson was designed only as an introduction to proportions.

Student test performance. The indicated TEKS to be addressed during a particular time interval are evaluated by a district assessment at the end of each nine-week grading period. In order to determine student achievement for the selected mathematics topic, the researcher ran a means comparison of students' performance on the district assessment based on the questions addressing only the appropriate TEKS taught during the research lesson. *Edusoft* (http://www.edusoft.com) was used to analyze student achievement on the assessment questions related to the research lesson's TEKS.

An analysis of the district sixth grade exam revealed nine questions addressed ratios and proportional situations. Table 21 reveals the percentage of students who answered the nine questions correctly from Taylor's seventh period academic class (who participated in the research lesson), all sixth grade academic classes taught by Taylor, and all sixth grade academic classes in the district. It should be noted that Taylor taught the research lesson not only to her seventh period class but to all her classes.

Based on the following data, Taylor's seventh period class only outperformed the overall percentages of the district on questions 14 and 18. Question 14 asked, "A can of mixed nuts holds eight ounces of cashews and 24 ounces of peanuts. What is the ratio of cashews to peanuts in this can of nuts?" Question 18 asked, "The ratio of red rosebushes to yellow rosebushes in the school garden is about three to four. If there were 36 yellow rosebushes, about how many red rosebushes would there be?" In addition to questions 14 and 18, Taylor's classes as a whole outperformed the overall percentages of the district on questions 6 and 16. The reader should recall that this research lesson was designed to introduce the students to the concept of proportions. According to Allison, "This is an intro lesson that will make some lasting impressions to really help the students remember."

Table 21

Patton Middle School
Students' Achievement on the Second Nine Weeks District Assessment

Assessment Question	Taylor's 7th period (% correct) academic	Taylor's classes (% correct) academic	District (% correct) academic
Question 6	25%	47%	44%
Question 7	19%	32%	36%
Question 11	25%	24%	32%
Question 14	69%	66%	62%
Question 16	56%	76%	70%
Question 18	50%	49%	49%
Question 20	25%	33%	40%
Question 22	12%	28%	39%
Question 23	12%	25%	32%

During the first planning session Taylor volunteered to teach the research lesson to her seventh period "regular" students based on the class size. Taylor's seventh period class had twenty-two students which the group thought would be an appropriate size. It should also be noted that Taylor described this particular group of students as very creative, but very challenging; however, she felt even this difficult class would be interested in the research lesson. Even though there appears to be some contributing factors to Taylor's students' low performance; overall, the evidence supports a limited impact on student achievement.

Case Study D: Students' Engagement

Based on comments by the teachers and the "knowledgeable other" during the reflection session, evidence suggests there was an impact on students' engagement in mathematics. According to Paige, "My group never gave up." Paige said that one young man appeared not to be engaged because he let his other two group members negotiate the strategies and then he suddenly joined in. Paige said, "I could tell by the look in his eyes he was constantly working." The "knowledgeable other" said, "My group was really exploring. They were trying so many different ways of looking at it." Paige agreed and concluded by saying, "Great group dynamics because everybody took part."

The "knowledgeable other" shared with the group that she thought students did achieve based on the research theme. The research theme was, "For students to develop effective communication skills and problem-solving skills to be marketable to business and to excel in society." According to the "knowledgeable other,"

> I felt that the teachers had planned a very good lesson to meet their research theme. I was able to see from the group that I observed that the students were developing effective communication skills and problem-solving skills. Though the students did not solve the problem correctly, they were exploring different strategies to use.

As a follow-up to the research lesson, Taylor had students individually write their thoughts about the lesson. The following statements are from participating sixth grade students:

- What I liked about the whole thing was the challenge of figuring out what we had to do and doing it. I liked it when we had to use our brains.
- What was hard was thinking hard.
- I thought we did great. Sometimes we wouldn't agree, but that helped us figure out our answer even better.
- The thing I liked was when we had to come up with an idea.

Conclusion on Effects on Students

Based on the prior descriptive statements and statistics, evidence indicated there was an impact on students' content knowledge in mathematics. In summarizing the discussion on student understanding, the "knowledgeable other" asked, "Do we think that they realized there was this ratio between their feet and your height to make that comparison?" Taylor answered, "Not yet." Charles said, "I don't think so." Lauren answered, "No." However, Paige answered,

> I think some in my group did because Robert kept putting his foot on the footprint and kept going, "That much bigger and how tall am I?" They were making that connection. "If his foot is bigger than mine, and I'm this tall, we got to make him taller." They made that connection, but they got hung-up on how to get inches; how to get measurement to it. But the overall concept, they got.

Taylor did agree that every group picked up the foot, looked at it, and tried to do something with it. Charles concluded, "Well, that's what we wanted them to do. We just wanted them to explore."

The "knowledgeable other" concluded by stating, "The students were weak in understanding how to create a proportion." However, the objective to have students explore a situation that introduces the concept of proportions was accomplished. According to Taylor, "Well, it's a beginning; they'll remember this. I probably have no idea how many times I will refer back to this lesson. It is definitely a beginning."

Evidence is limited on the impact lesson study had on Patton Middle School students' achievement in mathematics. Taylor's classes scored slightly higher or at the district percentages in four out of nine targeted questions which indicated a slight impact on student achievement. The research lesson, however, was designed to be an exploratory introduction to proportions.

Evidence does support that lesson study had an impact on students' engagement in mathematics. According to one of the student groups from Patton Middle School,

> The first thing we did was sit on the floor and then we started to talk about the foot, the big green foot. We had told each other stuff, and we studied the foot. Then we had to think about what we had to know. Then we had to put our feet together and come up with the size of the foot.

Based on the students' self-report, it appears students were engaged and actively participating in a problem-solving task Evidence suggests that students learn best when they are required to construct their own knowledge (NCTM, 2000; Wiske, 1998; National Research Council, 2000) and actively engaged in the learning task (Garet et al., 2001).

Cross-Case Analysis

A cross-case analysis was done in order to identify emerging themes on the effects lesson study had on teachers' instructional practices and content knowledge and to identify emerging themes on the effects lesson study had on students' conceptual understanding and achievement in mathematics. A cross-case analysis began with the researchers' use of a cross tabulation of the pre and post survey data, then followed by running a Greenville analysis through the use of the sixth version of non-numerical unstructured data indexing, searching, and theorizing (N6) software program (Richards, 2002), analyzing the district second nine week assessment scores, and analyzing reflective statements from "knowledgeable others," participating teachers and students. Table 22 relates the five categories concerning the impact on teachers and students across cases. Lesson study appeared to have an effect on teachers' instructional strategies and students' engagement in mathematics for all three case studies. In addition, lesson study had an impact on teachers' and students' content knowledge as well as student achievement in two out of the three case studies.

Table 22

Cross-Case Analysis on Participating Teachers

Categories	Case Study B: Madison M. S.	Case Study C: Greenville M. S.	Case Study D: Patton M. S.
Teachers' Instructional Practices	x	x	x
Teachers' Content Knowledge		x	x
Students' Conceptual Understanding		x	x
Students' Achievement		x	x
Students' Engagement	x	x	x

Table 23

Cross-Case Analysis on Teachers' Instructional Strategies

Categories	Case Study B: Madison M. S.	Case Study C: Greenville M. S.	Case Study D: Patton M. S.
Self-reflection and Modified Lessons	x	x	x
Problem-Solving with Hands-On Activity	x	x	x
Discovery Approach		x	x
Focus on Conceptual Understanding		x	x
Cooperative Learning	x	x	x
Prior Knowledge		x	x

The Impact of Lesson Study on Teachers' Instructional Practices

Table 23 displays the areas in which lesson study impacted the participating teachers' instructional practices. The common themes throughout the three case studies included: 1) self-reflection on instructional strategies, 2) engaging problem-solving activities, and 3) students working collaboratively.

Self-reflection. According to one of the "knowledgeable others," "We seldom have the opportunity to really think and plan (collectively) our teaching, then reflect on our teaching after the fact. Any attention to our own teaching, or teaching in general, like what we experienced with the lesson study experiment triggers new insights and perspectives on our teaching." Ashton said one of the greatest benefits about lesson study was the insight it allowed teachers to have on their own teaching. According to Ashton, "As a teacher, you do not get to see all that goes on in the classroom, so reflection time allows you to hear what went well and what needs to be improved without any judgments." Charles agreed that lesson study did lend itself to improving instructional practices. According to Charles,

> The lesson study made me more aware of my own teaching practices. Anytime I see someone else teach, I compare and contrast what they are doing with what I would do; therefore, it causes me to self-evaluate and make changes that better my classroom.

The impact of self-reflection, resulting from lesson study, showed an increase in teachers' opinions of their own teaching. Based on an analysis of the pre and post Mathematics Teacher Survey (Appendix C), there was a difference in how the teachers' viewed their own teaching (refer to Table 5). After participating in lesson study, five out of 13 teachers' opinion of their own mastery level of teaching increased. For instance, Gladys, Charles, Lauren, and Allison originally disagreed with considering themselves to be master mathematics teachers to having no opinion. In other words, they began to change their minds on their abilities of teaching. Diann went from no opinion on whether or not she was a master mathematics teacher to agreeing that she was a master teacher. Teachers must have opportunities to reflect on their own teaching and instructional strategies. In addition, when teachers are able to collaborate with their colleagues, evidence indicates a positive change in instructional strategies (Guskey, 2000; Stigler & Hiebert, 1999).

Problem-solving activities. According to Smith (2001) students should be engaged in challenging mathematical tasks. All three case study groups designed their research lessons around a mathematical activity where students were encouraged to use a hands-on approach to problem-solving. For example, one group of teachers challenged their students to determine the height of monsters based only on a paw print. According to one of the sixth grade students from Patton Middle School, “What I liked about the whole thing was the challenge of figuring out what we had to do and doing it.” Another sixth grader said, “I liked that the teachers made ratios more creative.” A third sixth grade student said, “The thing I liked was when we had to come up with an idea.”

As indicated by Hart (2000), middle school is a critical time in which students’ transition from concrete to abstract and through the use of hands-on materials and problem-solving tasks; middle school students are able to successfully make this transition. The case study groups incorporated hands-on materials such as rulers, paperclips, and footprints that engaged students in the mathematical investigations. Through the design of such activities evidence suggests lesson study did impact teachers’ instructional practices. Based on an analysis of the pre and post Mathematics Teacher Survey, out of 13 teachers, four increased their use of mathematical investigations after their participation in lesson study. Sally went from having students work on an extended mathematics investigation sometimes (once or twice a month) to often (once or twice a week). Lauren went from rarely having students do mathematical investigations (a few times a year) to sometimes (once or twice a month). Allison went from sometimes to often and Taylor from never to rarely.

Student collaboration. According to NCTM (2000), students should be encouraged to talk about, write about, describe, and explain mathematical ideas and concepts. All three case studies incorporated student collaboration during the research lessons. Each lesson study group planned lesson activities for students to collaboratively work in groups of three to four. Even during the reflection session when some teachers determined the lesson would be more effective with smaller groups, students were still expected to work together in pairs.

Throughout the planning sessions, teachers discussed the most effective grouping for student collaboration. According to Gladys, who had taught the activity prior to the research lesson, "Four was too many." Rachel, who had also previously taught the lesson said, "Three was fine for me." The other teachers agreed that four students to a group were too many and two students did not allow for enough discussion. During the reflection session, the teachers were pleased with the collaboration of the students and decided to continue grouping students by threes when re-teaching the lesson.

Participating teachers discussed not only what seemed to be an effective group size, but the task each student would be responsible for in their cooperative groups. Taylor said that she, too, thought students worked well in threes. According to Allison, "Three is the right number because one is measuring, one is recording, and one is like being the feet and everything." During the reflection sessions, teachers commented on the success of the students working together. The students seemed to like working together as well. According to one sixth grader, "I liked working with our group and trying to figure out how long the foot was."

The use of grouping students to promote collaboration and communication among students did impact teachers' individual instructional practices by increasing the frequency of group work. Based on an analysis of the pre and post Mathematics Teacher Survey, out of 13 teachers four increased the frequency of allowing students to work in groups; none decreased in their frequency. For example, Ashton went from often (once for twice a week) to all or almost all lessons. Vinson went from sometimes (once or twice a month) to all or almost all lessons. Kay went from sometimes to often and Allison went from often to all or almost all lessons. According to one of the "knowledgeable others," "The teachers shared the information that they had learned about having students work in groups to solve a problem. The teachers in their discussion after the lesson presentation seemed to agree that more opportunities needed to be provided for students to work in groups on problem-solving activities."

The Impact of Lesson Study on Teachers' Content Knowledge

Table 24 displays the areas in which lesson study impacted the participating teachers' content knowledge in mathematics for two out of the three cases. Evidence suggests teachers deepened their content knowledge in the following three ways: 1) sharing thoughts and ideas with colleagues, 2) understanding the alignment of the curriculum, and 3) predicting students' responses.

Table 24

Cross-Case Analysis on Teachers' Content Knowledge

Categories	Case Study B: Madison M. S.	Case Study C: Greenville M. S.	Case Study D: Patton M. S.
Collaborate with Colleagues		x	x
Mathematical Connections and the Curriculum		x	x
Student Responses		x	x

Collaboration. As a result of collaboration among teachers throughout the planning of the lessons, the observations of the lessons, and the opportunity to reflect on the research lessons and students' understanding, evidence suggests that lesson study did have an impact on content knowledge for some teachers. One "knowledgeable other" stated, "I think it certainly made them think about their instructional knowledge in general and their own instruction." Charles commented, "The lesson study made me more aware of my own teaching practices" supports what the "knowledgeable other" observed. According to one participant, "The obvious benefit of lesson study is being able to view your teaching through the eyes of students and colleagues. Teachers at times have the opportunity to collaboratively work on a lesson; however, traditional collaboration usually ends there where as lesson study provided a new perspective on our practice." According to Ashton, a classroom teacher from Highland Middle School, her content knowledge was improved as a result of joining teachers from another campus and hearing their ideas and approaches to teaching a particular topic. Randy also commented that being the only seventh grade teacher in his school limited his ability to collaborate on different instructional strategies; however, as a result of lesson study, he was able to discover new approaches to teaching proportional reasonableness. Consequently, deepening his content knowledge by seeing topics taught in a new approach.

Mathematical connections. Teachers strengthened their content knowledge by better understanding the curriculum. On October 16, 2004, participating teachers were asked to analyze the curriculum for grades 6, 7, and 8 for the second nine weeks of the school year. Teachers were able to identify content areas in which students struggled. Each group was then asked to create a knowledge package. According to Liping Ma (1999), a knowledge package forces teachers to identify the ideas and concepts needed for students to master a specific skill. Consequently, by teachers listing and discussing the connecting skills and topics, they strengthened their own content knowledge. According to Charles, "It was hard to identify a specific skill." According to Evan, a first year teacher, "Lesson study gave me more of a base of where to start or finish a mathematical concept." A "knowledgeable other" commented, "Subject matter knowledge was deepened through the development of a problem for students to solve. The teachers discussed what information the students would need to know about proportions in order to solve the problem."

Not only did lesson study enable teachers to see content connections but grade level connections as well. According to Taylor, a sixth grade teacher, "Having seventh and eighth grade teachers in the planning did help me see the vertical planning of ratio and proportion through the middle years." Teachers consistently agreed that it was helpful to research the content strand from previous grade levels in order to see the depth each concept was taught throughout the years.

Predicting student responses. One element in the lesson plan format (Appendix I) required teachers to anticipate students' responses throughout the research lesson. This particular element forced teachers to think like the students which increased their own content knowledge by foreseeing challenging areas as well as mathematical connections. For example, it forced teachers to think about students' prior knowledge. According to Charles, a classroom teacher from Patton Middle School, "Trying to think like the students would think during the lesson made me have to look at the lesson as if I was learning it for the first time." Allison said, "I think it helped my instructional knowledge by being able to discuss the finer details like questioning strategies or expected responses." A "knowledgeable other" also commented, "It is essential to think about anticipating student responses and misunderstandings not only to improve student understanding but our own."

There were limitations to the strengthening of teachers' content knowledge in that not all participating teachers benefited from the full potential of lesson study. Case Study B: Madison Middle School focused only on the activity with little thought to the mathematics content. For example, when planning the lesson, the participating teachers predicted students' questions to address lower cognitive thinking skills such as, "How big is a centimeter? What if the ruler is between two lines?" These predicted questions do not warrant a deep conceptual understanding in mathematics.

Even though there were limitations to the increase in teachers' content knowledge, improvements were made. Evidence suggests teachers' content knowledge improved based on collaboration with colleagues during the planning and reflection sessions. Teachers' content knowledge also improved by their understanding horizontal and vertical curricula alignments. Research also suggests that through teacher collaboration, instructional strategies will improve relating to teachers having a deeper content knowledge (Kwakman, 2003; Stigler & Hiebert, 1999; Fernandez, Cannon, & Chokshi, 2003).

The Impact of Lesson Study on Students' Conceptual Understanding

Table 25 displays the cross-case analysis for students' conceptual understanding in mathematics. Evidence suggests that there was an impact on student content understanding in two of the three case studies. According to the cross-case analysis students: 1) increased their understanding on the lesson topic and 2) increased their understanding through communication.

Table 25

Cross-Case Analysis on Students' Content Understanding

Categories	Case Study B: Madison M. S.	Case Study C: Greenville M. S.	Case Study D: Patton M. S.
Topic Understanding		x	x
Mathematical Connections		x	x
Collaboration		x	x

Lesson topic understanding. In case study groups C and D, participating teachers concluded students did master the lesson objectives. Both groups agreed that the students did comprehend the concept of proportional reasoning; however there was some debate between the observers from Case Study D on whether or not students really did understand proportions. The objective for this particular research lesson was to introduce students to the concept of proportions; therefore, observers determined students did achieve the overall objective.

Research indicates students' conceptual understanding increases as a result of students constructing their own knowledge (National Research Council, 2001a; Franke, Fennema, & Carpenter, 1997; Smith, 2001). Students from Greenville and Patton Middle Schools were able to discover proportional reasoning and ultimately increase their conceptual understanding. There was virtually no evidence to support an increase in students' conceptual understanding in mathematics from Madison Middle School.

Student collaboration. NCTM (2000) suggests to teach in a way that reflects the process standards is one of the best ways to teach and promote student understanding. Students were expected to communicate their ideas and problem-solving strategies in case studies C and D which led to an increase in conceptual understanding. It should be noted, students were expected to communicate in Case Study B; however, the communication between students pertained to estimates and actual facial measurements with limited discussions on conceptual understanding.

During the research lessons, observers were able to record student conversations which supported conceptual understanding through a discovery approach and collaboration. For example, the following conversation represents a discussion between two students:

> Dreon: I think he would be six feet.
> Dakota: I say eight.
> Dreon: We need a ruler (started measuring with his pencil).
> Dreon: We need something like a foot. Our feet are much smaller, and I'm five feet tall. How tall are you?
> Dakota: I want to go to ten.
> Dreon: You want to round it up?
> Robert: This is twelve so it's like a foot (measuring foot with his fingers).

According to another student, “The thing I liked is when we had to come up with an idea.” Another student commented, “I thought we did great. Sometimes we wouldn’t agree, but that helped us figure out our answer even better.”

The Impact of Lesson Study on Students’ Achievement

Throughout the analysis on student achievement, only one out of the three case studies consistently scored higher on the targeted questions from the second nine week district assessment. Case Study B had no supporting evidence on student achievement from the district assessment as a result of selecting a topic that was not evaluated. Students in Case Study C did result in a higher percentage on all four targeted questions when the 7th grade lead teacher’s academic classes were compared to the 7th grade academic students in the district. The reader should recall that the research lesson was taught to all academic classes. Case Study D resulted in the students scoring higher on approximately one-third of the targeted questions when the 6th grade lead teacher’s academic classes were compared to 6th grade academic students in the district. All 6th grade classes taught by the lead teacher were compared as a result of the research lesson being taught to all classes. Based on one research lesson per group and the use of a district nine week assessment, evidence was limited on the impact lesson study had on student achievement in mathematics.

The Impact of Lesson Study on Students’ Engagement

A third theme emerged during the analysis on the impact of lesson study pertaining to students. All teachers from the three case studies commented on the increased level of student engagement throughout the research lessons. Several teachers commented that they saw students who normally did not engage in lesson activities actively participate in the research lesson. Sally, one of the classroom teachers from Case Study B stated, "The students were very much into the lesson; they loved it." Sally continued to say that seeing John, an eighth grade student, engaged in the lesson showed her that he could participate in the classroom. According to Randy, "The students were more on task today." The seventh grade students at Greenville Middle School were actively engaged and excited about determining whether objects were proportional by the use of paperclips. According to the "knowledgeable other," "When the students got the paperclips, they seemed really interested in hooking them together and seeing how they compared and measuring with them." Ashton commented that she noticed one of the students who normally did not participate in class discussions or activities actually graphed the data for his group. According to Ashton, "He took the initiative when it was time to come up and plot the points on the graph." Taylor, the lead teacher from Case Study D, commented that some students who usually follow along with the ideas from other students actually took on a leadership role. Taylor said, "Haley was bossing her group around; however, Chelsea started taking control because she had some ideas." Paige also commented that Dreon jumped in as the leader the moment Trevon had to leave. One student from Patton Middle School even stated, "I really liked the way all group members were exploring." Overall, students were actively involved in the research lessons and different students took on leadership roles.

Lesson Study as a Catalyst

The following discussion will focus on research question three: Does the participation in lesson study as a form of professional development serve as a catalyst for the growth and continuation of lesson study within the middle school mathematics community? In addressing this question, an analysis of the teachers' participation logs, teachers' commitments, and future plans for participation in lesson study will be discussed.

In order to assess each teachers' level of participation in lesson study, teachers were asked to keep a running record of the time spent collaborating with colleagues, researching the lesson topic, and planning the lesson. Table 26 summarizes the amount of time teachers spent preparing for the research lesson. The times do not include the presentation of the research lesson or the two-hour reflection sessions.

Based on the information below, each case study spent over twenty hours preparing for their research lessons. Teachers spent an average of about 5.7 hours planning for the research lesson. Time was spent developing the instructional plan, typing the lesson plan, and gathering and preparing the materials.

Table 26

Teacher Preparation Time for Research Lesson as reported by Participants

Participants	Time Preparing for Research Lesson (n = hours)
Case Study B	
Diann	5.25
Sally	5.25
Kay	5.25
Vinson	7.25
Case Study C	
Randy	9.0
Rachel	6.0
Ashton	3.0
Gladys	4.0
Case Study D	
Charles	9.0
Taylor	5.75
Allison	8.0
Evan	6.0
Lauren	0.5

After each group completed the lesson study cycle, all participants were invited back to the local private university to share their experiences with lesson study. The GEAR UP Project Director for the Mathematics Initiative and the researcher had planned to have the sharing of research lessons on a Saturday, in January, similar to the October 16, 2004, initial lesson study professional development day. However, it was determined that conflicts with the districts calendar prohibited a full day's meeting. The lesson study sharing and reflection was offered in two three-hour sessions instead of one six-hour session. The first session was on February 8, 2005, from 4:30-7:30 p.m. Out of the 13 teachers in this study, eight were unable to attend due to school related activities and other commitments.

The session began by the Project Director welcoming returning participants as well as new participants. The Director then gave an overview of the lesson study cycle and invited each group to share their experiences from the fall '04 lesson studies. In order to assist with their presentations, the GEAR UP Math Project Director sent a *PowerPoint* template to each lesson study group prior to the meeting. The template included the following slides:

- Objective of the research lesson
- Lesson sequence
- Observations from the planning process
- Observations from the reflection session
- Overall benefits and issues

Ashton, from Case Study C, explained their lesson objective and sequence. Charles, from Case Study D, explained their lesson objective and sequence. No participating teacher from Case Study B was present; therefore, the researcher shared their lesson objective and sequence with the others. In addition, each presenter shared their experiences throughout the phases of the lesson study cycle. Representatives from two other lesson study groups also shared their experiences. Table 27 summarizes the benefits and issues stated by representatives from case studies C and D. Overall, the greatest benefit to lesson study appeared to be the collaboration with others whether it was with teachers from other campuses or on the same campus. The major issue appeared to be time. Finding the time to plan and reflect collaboratively was often a challenge.

Table 27

Teachers' Self-Report on the Benefits and Issues of Lesson Study

Participants	Benefits	Issues
Case Study C	Working with another campus	Time for planning and reflecting
Case Study D	Forced to think thoroughly Collaboration with peers Great concept	Time and scheduling Small campus

After hearing about the experiences of all five lesson study groups, participants were given the opportunity to participate in the spring '05 lesson studies. The following teachers elected to either begin or continue their experience with lesson study.

Case Study B

Sally, Diann, Vinson, and Kay, the four teachers from Madison Middle School, did not attend the two three-hour professional development sessions offered during

February '05 and elected not to continue for a second lesson study cycle. No specific reasons were given for not continuing with lesson study.

Case Study C

Randy and Rachel, the two teachers from Greenville Middle School, did not continue for a second lesson study cycle. According to the self-reported teachers' log, both Randy and Taylor spent over the average amount of planning time in preparing for the first research lesson. This, consequently, may have resulted in their decision not to continue based on time restraints. Gladys and Ashton, the two teachers from Highland Middle School, did elect to participate in a second lesson study cycle. Not only did they want to continue with lesson study, but they wanted their next research lesson to occur on their own campus. Consequently, Ashton recruited three additional teachers from Highland Middle School to participate. Ashton recruited an eighth grade mathematics teacher, the computer teacher, and the special education teacher.

Case Study D

Charles, Taylor, Allison, and Evan, the four teachers from Patton Middle School, all elected to participate in a second lesson study cycle. According to the self-reported teachers' log, Lauren spent little time planning for the first research lesson as a result of the inconvenience of traveling to another campus. Because Lauren wanted to participate in a second lesson study cycle, she recruited two new participants from her own campus to join her in the next cycle.

Over 50 percent of the participants in this study did elect to engage in a second lesson study cycle for spring '05. In addition, five new teachers joined these returning participants. For the purpose of this study, data was gathered only for fall '04. It should, however, be noted that not only did the majority of fall participants continue in the spring, but Patton Middle School mathematics teachers even petitioned their administration for a common conference period so that they could utilize lesson study throughout the 2005-2006 academic school year.

Summary

Does participation in lesson study serve as a catalyst for growth and continuation? Evidence suggests that this is the case. Evidence suggests that the participants who did not continue the lesson study process during spring '05 were due to the lack of time. According to one “knowledgeable other,”

> Time was a precious commodity that was difficult to find during the first round and prevented a second round of lesson study from occurring. Even though the teachers saw and experienced the benefits that lesson study had to offer, the stress of everyday existence caused anxiety during the first round and prevented a second round from occurring.

Previous studies indicated finding time to do lesson study was a challenge (Perry, Lewis, & Akiba, 2002; Lewis, 2002a). Even though time was an issue for all participants in this study, the benefits outweighed the time factor for most. According to Charles, a participant and department chair who petitioned his administration for a common planning period with the mathematics teachers, “The obvious benefit of lesson study is to provide students with quality lessons on teaching math concepts. Many teachers also found that collaboration time is even more valuable to the curriculum.”

CHAPTER FIVE

Summary and Discussion

United States' students have consistently performed well below that of most Asian students, particularly Japanese, and students in many European countries in the field of mathematics (U.S. Department of Education, 2003; National Research Council; 2001a). According to Darling-Hammond and Sykes (1999) the professional development of teachers is essential to improving the instructional practices and ultimately students' performance. Calls for improvements in professional development have strengthened over the last few years (National Research Council, 2002a; Stigler & Hiebert, 1999) and studies have found collaboration among teachers to be a vital element in translating ideas into practices (Johnson & Blair, 1999; Smith, 2001). As a result, educators in the United States are currently interested in the Japanese form of professional development known as lesson study. Lesson study can be defined as a teacher-led instructional improvement cycle in which teachers work collaboratively to: formulate goals for student learning, plan a research lesson, teach and/or observe the lesson, reflect on the gathered evidence, revise the lesson for improvement, and re-teach the revised lesson (Perry & Lewis 2003; Curcio, 2002). Even with the long Japanese history of lesson study and the spreading interest across the United States, there has been little public discussion about how lesson study impacts teachers and students, particularly at the middle and secondary levels (Lewis, Perry, & Murata, 2004; Perry, Lewis, & Akiba, 2002; Stigler & Hiebert, 1999).

The purpose of the current study was threefold. First, while many schools are engaging in lesson study, few studies have examined the impact lesson study has on teachers' beliefs in instructional practices or how lesson study can improve teachers' content knowledge. Current readings pertaining to lesson study focus on how to design and implement the lesson cycle (Lewis, 2002b). In addition, the overwhelming majority of literature available on lesson study in the United States pertains to experiences at the elementary level (Perry, Lewis, & Akiba, 2002; Perry, Lewis, & Murata, 2003). The purpose was to extend the current literature through descriptive statistics that contribute to the impact lesson study has on teachers' instructional practices and content knowledge, specifically at the middle school level.

Second, studies pertaining to the impact lesson study has on students is practically non-existent. The literature that is available on lesson study seems to focus either on how to implement lesson study (Lewis, 2002b; Stigler & Hiebert, 1999; Perry, Lewis, & Akiba, 2002) or the relationship of lesson study to teachers' knowledge development (Lewis, Perry, & Murata, 2003). Therefore, this study attempted to identify the impact lesson study had on students' conceptual understanding and achievement in mathematics. The purpose was to extend the current literature through descriptive statistics, specifically at the middle school level.

Third, although interest in lesson study has increased the United States, is this a short term interest? Lewis (2002a) asked the question of whether or not lesson study has a sustained future in the United States as a form of professional development or was it another "fad" in the current education movement? Therefore, the third purpose of this study was to examine whether participation in lesson study would serve as a catalyst for the growth and continuation of lesson study.

The participants in this study consisted of 13 middle school mathematics teachers from five out of seven middle schools in an urban school district in central Texas. These teachers were identified through a criterion based purposeful sample approach in that they met the following criteria: middle school mathematics teacher in the study's identified school district, participated in the study's GEAR UP Mathematics Initiative, and assigned a different "knowledgeable other" to guide them through the lesson study cycle.

As a means to triangulate data, nine different qualitative measures were used throughout the study. Two baseline surveys were collected on all middle school mathematics teachers who participated in the study with one survey serving as a pre and post instrument. Data was also gathered through teacher logs, planning and reflection session transcripts, observation notes, lesson plans, student work, district assessment, and electronic discussions. Throughout the analysis of data, every attempt was made to eliminate bias and to establish validity through soliciting an outside mathematics specialist from the local private university to review entire transcripts and coding of the data.

The examination of the research questions and the coding of data directed the process of analyzing the qualitative data collected. Question one addressed the impact lesson study had on middle school mathematics teachers. Question two addressed the impact lesson study had on middle school students' in the field of mathematics. Question three examined whether participation in lesson study would serve as a catalyst for growth and continuation in lesson study.

Summary of Results

Impact on Teachers

Research question one addressed what effects lesson study had on middle school mathematics teachers. In order to address this question, data was gathered and analyzed from the following sources:

- Mathematics Teacher Survey
- Observation notes
- Lesson plans
- Electronic discussion board
- Planning transcripts
- Reflection transcripts

Results indicated that lesson study did impact middle school mathematics teachers. Evidence supported participating teachers' beliefs in instructional practices had a positive effect in three areas: self-reflection on instructional strategies, engaging problem-solving activities, and students working collaboratively. Results also indicated some middle school mathematics teachers increased their content knowledge by: sharing thoughts and ideas with colleagues and increasing their understanding of curriculum alignment. Evidence also indicated that teachers' increase in content knowledge was limited as a result of more focus on the mathematics activity and less focus on the concept behind the activity.

Impact on Students

The second research question addressed the effects lesson study had on middle school mathematics students through analyzing data from the following sources:

- Observation notes
- Student work
- District nine-week assessment
- Reflection transcripts

Results indicated that lesson study did increase students' mathematics understanding in two of the three case studies. Evidence suggested students gained content understanding by communicating their thoughts and ideas and by constructing their own knowledge in mathematics by engaging in problem-solving activities.

Evidence indicated students from Case Study C (Greenville Middle School) showed achievement by higher performance on four out of four targeted questions from the district nine week assessment. In addition, findings suggested students from Case Study D (Patton Middle School) showed limited achievement by higher performance on four out of nine targeted questions from the district nine week assessment. Therefore, caution must be exercised when attempting to generalize the effects lesson study had on students' achievement. Throughout the analysis of data, a third theme emerged as an effect lesson study had on students. Student engagement seemed to be a common theme in that all participating teachers commented on the increased student participation and leadership that resulted from lesson study.

Growth and Continuation of Lesson Study

Research question three asked: Did the participation in lesson study serve as a catalyst for the growth and continuation of lesson study within the middle school mathematics community? In order to analyze this question, data was gathered from the following sources:

- Teacher logs

- Electronic discussion board
- Teachers reflecting at a follow-up professional development session

Evidence supported that participation in lesson study did serve as a catalyst for continuation and growth. Approximately 54% of the participating teachers engaged in a second lesson study during spring ’05. No teachers from Case Study B, which was identified as Madison Middle School, attended the first three-hour professional development session in February ’05 which was designed for teachers to share and reflect on their experiences with lesson study. In addition, no teachers from Case Study B attended the second three-hour professional development session, in February ’05, which was designed to begin the initial planning for a second lesson study. Fifty percent of the teachers from Case Study C, which was identified as Greenville Middle School, engaged in a second lesson study during spring ’05. The reader should recall Case Study C consisted of two teachers from Greenville Middle School and two teachers from Highland Middle School. The two teachers from Highland Middle School who continued with lesson study recruited three additional teachers from their school. Finally 100% of the teachers from Case Study D, which was identified as Patton Middle School, engaged in a second lesson study during spring ’05. Case Study D consisted of four teachers from Patton Middle School and one teacher from Eastland Middle School. Patton Middle School teachers also petitioned their administration for a common planning period so that they could continue with lesson study during the upcoming school year. The participating teacher from Eastland Middle School recruited two additional teachers from her school to participate in lesson study during spring ‘05.

Relationship to Research Literature

Based on prior studies, there appeared to be four common elements to successful professional development. First, there had to be a primary focus on issues related to learning and learners. Second, teachers needed opportunities to collaborate on their teaching and instructional matters. Third, there had to be sustained efforts and changes in small, incremental steps. Finally, professional development had to be embedded in the learning environment (Guskey, 2000; Loucks-Horsley, et al., 2003; Gearhart et al., 1999). Lesson study, the Japanese form of professional development, contains the elements researchers such as Thomas Guskey (2000) has recognized as essential elements to positively influence instructional change in the classroom. Guskey stressed that professional development must focus on issues related to learning and learners. The participants in the current study did focus on learning issues related to their students.

On October 16, 2004, teachers analyzed the state and district curricula for the second nine weeks and selected specific content topics in which students were weak as the objective for their research lessons. According to Guskey (2000), professional development should take place in the learning environment and involve teacher collaboration. All lesson studies occurred in middle school mathematics classrooms after participating teachers spent at least two hours collaboratively planning their research lesson. In addition, teachers were able to observe the research lessons and collaborate for two hours following the lesson.

In Wilms' (2003) study, 92 percent of the teachers who participated in lesson study, agreed that lesson study enhanced their confidence and creativity which ultimately improved their instructional practices. The findings in this study supported the current literature. Participants reported increased confidence in their instructional practices.

Results from the Mathematics Teacher Survey showed a difference in teachers' opinions of their own instructional abilities. There was a significant increase in the number of teachers who viewed themselves to be a master teacher after participating in lesson study. Charles, a middle school teacher from Patton also commented, "Lesson study made me more aware of my own teaching practices. It is great to see someone else's teaching style because it makes you critique your own which allows you to improve."

As a result of collaboration, teachers also increased their understanding of the curriculum which resulted in an increase in their confidence. According to Wilms (2003), when teachers had greater knowledge and confidence, their instructional strategies improved. Findings from this research supported that teachers' became more aware of the curriculum as a result of collaboration. This in turn increased the teachers' content knowledge as well as their instructional knowledge. According to Taylor, "Having seventh and eighth grade teachers in the planning did help me see the vertical planning of ratio and proportion through the middle years." Therefore, as evidenced in the current study, lesson study did result in improved instructional practices.

Research findings indicated that teachers deepened their content knowledge as a result of participation in lesson study (Lewis, Perry, & Murata, 2003). According to Lewis, Perry, & Hurd (2004), as a result of teachers seeing the research lesson through the eyes of the students and predicting students' questions and responses while planning the lesson, teachers' content knowledge was deepened. Once again, findings from this research supported the current literature. One element in the lesson plan format required teachers to anticipate students' responses and questions throughout the research lesson. This particular element forced most teachers to think in terms of the students which increased their own content knowledge. "Trying to think like the students would think during the lesson made me have to look at the lesson as if I was learning it for the first time," said one teacher. A "knowledgeable other" also commented, "It is essential to think about anticipating students responses and misunderstandings not only to improve student understanding but our own."

Research indicated that students' conceptual understanding increased when given the opportunity to discover mathematics solutions (Perry, Lewis, & Akiba, 2002; National Research Council, 2001a). During this study, all participating teachers designed their research lessons around an engaging activity. Two out of three of the planned activities had students discover the meaning of proportional reasoning. Consequently, evidence supported students' conceptual understanding in both case studies; however, evidence of students' achievement was more limited.

As a result of United States' students scoring well below Asian students in international mathematics comparisons, instructional approaches in the U.S. and Japan gained widespread attention (Stigler & Hiebert, 1999; National Research Council, 2001a; U.S. Department of Education, 2003). Japanese lessons actively engaged students in problem-solving activities where as U.S. lessons consisted of teachers instructing the students in skills or concepts (National Research Council, 2001a; California State University, 1997). NCTM (2000) indicated that students' understanding and achievement in mathematics was directly related to the instructional strategies implemented in the classroom. Each lesson study group participating in this study engaged students in an activity, but based on students' performance on a district assessment, there was limited evidence on the impact lesson study had on students' achievement in mathematics. Caution is advised in interpreting and over-generalizing results based only on a district assessment. Overall, research is limited in supporting students' achievement as a direct result of lesson study (Linek et al., 2003; Hill, Rowan & Ball, 2005).

Past research on lesson study (Perry, Lewis, & Akiba, 2002) indicated that teachers reported finding time to participate in lesson study was a challenge. At the end of the initial day on professional development in lesson study, the researcher asked participating teachers what they thought the challenges would be in lesson study. The teachers' responses included:

- Time
- Finding ways to engage students in real-world problems
- Incorporating everyone's ideas and viewpoints into one lesson in order to accommodate everyone's needs

Teachers overwhelmingly listed time as their main concern which supported the findings of Perry, Lewis, & Akiba.

According to Perry, Lewis, & Akiba (2002), after the first year of lesson study, recruitment was easier by the testimony of teachers of who had participated in lesson study. As evidenced in this study, participating teachers who engaged in a second lesson study were able to recruit additional teachers from their schools. For the teachers who elected not to continue with lesson study, time constraints appeared to be the major factor. According to one "knowledgeable other,"

> Time was a precious commodity that was difficult to find during the first round and prevented a second round of lesson study from occurring. Even though the teachers saw and experienced the benefits that lesson study had to offer, the stress of everyday existence caused anxiety during the first round and prevented a second round from occurring.

At the close of the initial professional development session in lesson study, participating teachers were asked how they thought lesson study would help them. Teachers responded as follows:

- Better understanding of what I'm doing and how I'm reaching the kids
- Collaborating with other teachers in knowledge and different techniques/strategies
- Receive feedback on learning, planning, and teaching
- Better learn the mathematics curriculum
- Engage students to enjoy mathematics
- Focus on why instead of how

Evidence from this study supported many of the teachers' predictions as well as the current research literature. Participation in lesson study does positively affect teachers' instructional practices and content knowledge. In addition, lesson study increased students' conceptual understanding and engagement in mathematics. Evidence from this study is limited in whether lesson study had a positive effect on students' achievement in mathematics. Finally, findings of the current study provide support in that participation in lesson study does serve as a catalyst for growth and continuation in lesson study with time constraints as the biggest challenge.

Limitations of the Study

This study had several limitations. First, this was a multiple case study, which, according to Creswell (2003),

> The cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time (p. 15).

The case studies were bounded by one school district and held participants to a strict and possibly limiting time schedule as a result of implementing lesson study in one semester. Participants were introduced to lesson study, determined a research theme, engaged in a needs assessment in order to select a content topic, and developed a knowledge package in one day. Within three weeks, participants met for a two-hour planning session where groups planned their research lessons, determined their observation focus, and finalized plans for the research lesson. Following the planning session, participating groups taught the research lesson and engaged in a two-hour reflection session that same day.

Documentation was very limited on observations from some participants. Each observer was given the following observation guidelines:

- Remember that the observations are about the lesson and student understanding, not about the teacher.
- Do not help students or otherwise interfere with the natural flow of the lesson.
- Each observer should have a copy of the lesson plan, required material(s), and seating chart.
- Collect data for your assigned observation role. For those not assigned a particular observation focus, you should focus on the points to notice as indicated in the lesson plan.
- Observation forms attached.

Even with the guidelines, some participants did not record pertinent information which may have provided supporting evidence for the study.

A third limitation to this study pertains to student achievement. Student achievement was assessed based on students' performance on the district nine-week test with limited content validity.

Finally, there was no follow-up on the participants who elected not to continue with a second lesson study. Informal statements implied time constraint as the leading cause for not continuing with lesson study; however, no official data was collected to ascertain the actual reasons.

Implications for Future Research

Few studies have examined the impact lesson study has on students' understanding and achievement in mathematics related to lesson study. As to date, most studies have addressed how to implement lesson study in the United States (Lewis, 2002b; Fernandez & Yoshida, 2004; Perry & Lewis, 2003) or the effects lesson study has on teachers' instructional practices (Lewis, Perry, & Murata, 2003; Wilms, 2003; Stigler & Hiebert, 1999). Based on research, student understanding and achievement is implied as a result of improved instructional practices (NCTM, 2000; National Research Council, 2001a; Smith, 2001). Consequently, more studies need to focus on the impact lesson study has on student understanding and achievement. A longitudinal study is needed in order to confirm the assertion that lesson study impacts students' achievement. If teachers engaged in lesson study over a long period of time, students' performance on district and state assessments could be a means of comparison between individuals who do and do not participate in lesson study.

There needs to be more studies on the impact lesson study has on teachers and students particularly at the middle school grades. As indicated in chapter two, middle school age is the time in which students make a critical transition from concrete to abstract thinking based on Jean Piaget's periods of cognitive development. Around the age of 12, adolescents are able to think about abstractions and hypothetical concepts (Berger, 1988). As a result of this critical transition time, Hart (2000) argued that a child's success was dependent on the instructional practices present in the learning environment. For example, content topics should be related to prior knowledge and approached with confidence. As international comparisons in mathematics have shown, United States eighth grade students' performance was below the average of many other countries (Stigler & Hiebert, 1999; Atweh, Clarkson, & Nebres, 2003; U. S. Department of Education, 2003). As explained, middle school is a critical time for cognitive development and more studies need to focus on the impact lesson study has on teachers and students at this age level. A comparison study is needed in order to confirm the impact lesson study has on middle school teachers and students.

Lesson study is a teacher-led and teacher-driven form of professional development (Lewis, 2002b; Stigler & Hiebert, 1999). Teachers plan, observe, and reflect together on a research lesson; however, some lesson study groups also have a "knowledgeable other" present throughout the cycle. Future research should address the role of the "knowledgeable other." A "knowledgeable other" in Japan is also known as the outside advisor who serves the following three functions:

- Provides a different perspective when reacting to the research lesson
- Provides information about subject matter content, new ideas, or reforms
- Shares the findings of other lesson study groups

In addition to the above mentioned roles of the "knowledgeable other" some have served as support in encouraging teachers to continue the lesson study process while others have actually taught the planned research lesson (Lewis, 2002b; Watanabe & Wang-Iverson, 2002; Fernandez & Yoshida, 2004). In this study, the "knowledgeable other" served more as a facilitator and supporter throughout the lesson study cycle in order for teachers to feel ownership in the process. Consequently, some lesson activities may have been selected based on how "fun" they were with limited focus on the content. This begs the question of what is the true role of the "knowledgeable other?" Lesson study is teacher owned and driven; therefore, what role should the “knowledgeable other” play so that teachers are responsible for the lesson planning but yet lessons are designed around rich content topics and not just activities? More research is needed on the roles and responsibilities of the “knowledgeable other.”

More research is needed to determine the contributing factors that lead to the growth and continuation of lesson study. According to Perry, Lewis, & Akiba (2002), recruitment was easier by the testimony of teachers who had participated in lesson study; however, finding time to implement lesson study proved to be a challenge for teachers. Research is limited and inconclusive in this area and more studies need to focus on the necessary factors for lesson study to continue in the United States.

Finally, more research is needed to determine the impact lesson study has on teachers’ instructional practices after participation in lesson study. According to Lewis (2002b), lesson study does impact teachers’ instructional practices; however, more follow-up studies need to focus on whether these instructional changes transfer into classroom practice.

It is imperative for teachers to strive for continuous improvement in instructional strategies and content knowledge because teachers are the key to students’ understanding and achievement in mathematics (Dana & Yendol-Silva, 2003; Darling-Hammond, 1998). Successful instructional changes occur in sustained efforts and in small incremental steps (Guskey, 2000). Lesson study addresses one lesson at a time, but impacts learning and instruction in several aspects. Lesson study allows teachers to view teaching and learning as it occurs in the classroom. Lesson study also keeps students as the main focus. Lesson study is teacher-led which ultimately allows teachers to be actively involved in instructional change (Takahashi & Yoshida, 2004; Wilms, 2003).

With time, lesson study has the potential to build learning communities within schools and ultimately result in instructional improvement and increase in students' achievement.

APPENDICES

APPENDIX A

GEAR UP Math Initiative Agenda
October 16, 2004

8:00-8:30	**Sign-in and Coffee**
8:30-9:00	**Overview/Session Focus** Initial data collection
9:00-10:00	**Needs Assessment** • Identify a Theme • Analyze district & state curriculum expectations-School Level • Identify needs and strengths-School Level • Share with whole group • Examine commonalities & differences *Goal: To identify content topic to address in lesson planning*
10:00-10:15	**Break**
10:15-11:30	**Developing A Knowledge Package** • What is it? • How and why is it used? • Research identified content area using Math Ed Lab & LRC resources, district textbook & curriculum document, Internet resources, etc. *Goal: To develop a knowledge package for identified topic*
11:30-12:15	**Working Lunch** Sharing of Knowledge Package and research findings
12:15-1:45	**Lesson Study: What, Why, How** Overview, Process, Purpose *Goal: To explore how Lesson Study can facilitate teaching and learning*
1:45-2:30	***Black Board* Training** *Goal: To become proficient in use of Black Board to support collaboration*
2:30-3:30	**Next Steps/Reflection & Evaluation** Schedule next planning session Determine roles and assignments of each group member

APPENDIX B

Teacher Background Information

Please complete the following information. Any information you provide will be confidential.

Name of Participating Teacher____

Campus_________________________________ Date___________________________

Grade Level Currently Teaching:________________

Circle the characteristics that best describe YOU.

1. Gender: Male Female

2. Age: 20-29 30-39 40-49 50+

3. Ethnicity: Anglo Hispanic African American Other:______

Please describe your EDUCATION.

4. Circle the degrees you have completed and write in your area of expertise for each one.

Associate's Degree Area of Expertise__________________________________

Bachelor's Degree Area of Expertise__________________________________

Master's Degree Area of Expertise__________________________________

Specialist's Degree Area of Expertise__________________________________

Doctoral Degree Area of Expertise__________________________________

Other ____

Please indicate your TEACHING EXPERIENCE.

5. Number of Years COMPLETED in teaching:_________________________________

6. Number of Years COMPLETED in teaching mathematics:______________________

Please circle the range that best describes your level of participation in GEAR UP over the past 5 years.

7. Number of hours: less than 10 10-20 21-30 31-40 41-50 51-60 More than 60

APPENDIX C

Mathematics Teacher Survey

There are no right or wrong answers to the following questions. Please respond in light of your beliefs and practices in your own classroom. Any information you provide will be confidential.

1. Please provide your opinion about each of the following statements. (Fill in the appropriate circle.)

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
①	②	③	④	⑤

a. Students learn mathematics best in classes with students of similar abilities.

① ② ③ ④ ⑤

b. The testing program in my state/district dictates what mathematics content I teach.

① ② ③ ④ ⑤

c. I enjoy teaching mathematics.

① ② ③ ④ ⑤

d. I consider myself to be a “master” mathematics teacher.

① ② ③ ④ ⑤

e. I have time during the regular school week to work with my colleagues on mathematics curriculum and teaching.

① ② ③ ④ ⑤

f. My colleagues and I regularly share ideas and materials related to mathematics teaching.

① ② ③ ④ ⑤

g. Mathematics teachers in this school regularly observe each other teaching classes as part of sharing and improving instructional strategies.

① ② ③ ④ ⑤

h. Most mathematics teachers in this school contribute actively to making decisions about the mathematics curriculum.

① ② ③ ④ ⑤

2. Think about your plans for the mathematics classes you currently teach. How much emphasis will each of the following student objectives receive? (Fill in the appropriate circle.)

None	Minimal Emphasis	Moderate Emphasis	Heavy Emphasis
①	②	③	④

a. Increase students' interest in mathematics

① ② ③ ④

b. Learn mathematical concepts

① ② ③ ④

c. Learn mathematical algorithms/procedures

① ② ③ ④

d. Develop students' computational skills

① ② ③ ④

e. Learn how to solve math problems

① ② ③ ④

f. Learn how to reason mathematically

① ② ③ ④

g. Learn how mathematics ideas connect with one another

① ② ③ ④

h. Prepare for further study in mathematics

① ② ③ ④

i. Understand the logical structure of mathematics

① ② ③ ④

j. Learn about the history and nature of mathematics

① ② ③ ④

k. Learn to explain ideas in mathematics effectively

① ② ③ ④

l. Learn how to apply mathematics in business and industry

① ② ③ ④

m. Learn to perform computations with speed and accuracy

① ② ③ ④

3. About how often do you do each of the following in your mathematics instruction? (Circle the appropriate level.)

Never	Rarely (a few times a year)	Sometimes (once or twice a month)	Often (once or twice a week)	All or Almost All Lessons
①	②	③	④	⑤

a. Introduce content through formal presentations

① ② ③ ④ ⑤

b. Learn mathematical concepts

① ② ③ ④ ⑤

c. Engage the whole class in discussions

① ② ③ ④ ⑤

d. Require students to explain their reasoning when giving an answer

① ② ③ ④ ⑤

e. Ask students to explain concepts to one another

① ② ③ ④ ⑤

f. Ask students to consider alternative methods for solutions

① ② ③ ④ ⑤

g. Ask students to use multiple representations (e.g., numeric, graphic, geometric, etc.)

① ② ③ ④ ⑤

h. Allow students to work at their own pace

① ② ③ ④ ⑤

i. Help students see connections between mathematics and other disciplines

① ② ③ ④ ⑤

j. Assign mathematics homework

① ② ③ ④ ⑤

k. Read and comment on the reflections students have written, e.g., in their journals

① ② ③ ④ ⑤

4. About how often do students in your mathematics classes take part in the following types of activities? (Circle the appropriate level.)

Never	Rarely (a few times a year)	Sometimes (once or twice a month)	Often (once or twice a week)	All or Almost All Lessons
①	②	③	④	⑤

a. Listen and take notes during presentation by teacher

① ② ③ ④ ⑤

b. Work in groups

① ② ③ ④ ⑤

c. Read from a mathematics textbook in class

① ② ③ ④ ⑤

d. Read other (non-textbook) mathematics-related materials in class

① ② ③ ④ ⑤

e. Engage in mathematical activities using concrete materials

① ② ③ ④ ⑤

f. Practice routine computations/algorithms

① ② ③ ④ ⑤

g. Review homework/worksheet assignments

① ② ③ ④ ⑤

h. Follow specific instructions in an activity or investigation

① ② ③ ④ ⑤

i. Design their *own* activity or investigation

① ② ③ ④ ⑤

j. Use mathematical concepts to interpret and solve applied problems

① ② ③ ④ ⑤

k. Answer textbook or worksheet questions

① ② ③ ④ ⑤

Never	Rarely (a few times a year)	Sometimes (once or twice a month)	Often (once or twice a week)	All or Almost All Lessons
①	②	③	④	⑤

l. Record, represent, and/or analyze data

① ② ③ ④ ⑤

m. Write reflections (e.g., in a journal)

① ② ③ ④ ⑤

n. Make formal presentations to the rest of the class

① ② ③ ④ ⑤

o. Work on extended mathematics investigations or projects (a week or more in duration)

① ② ③ ④ ⑤

p. Use calculators or computers for learning or practicing skills

① ② ③ ④ ⑤

q. Use calculators or computers to develop conceptual understanding

① ② ③ ④ ⑤

r. Use calculators or computers as a tool (e.g., spreadsheets, data analysis)

① ② ③ ④ ⑤

5. About how often do students in your mathematics classes use calculators/computers to:

Never	Rarely (a few times a year)	Sometimes (once or twice a month)	Often (once or twice a week)	All or Almost All Lessons
①	②	③	④	⑤

a. Do drill and practice

① ② ③ ④ ⑤

b. Demonstrate mathematics principles

① ② ③ ④ ⑤

c. Play mathematics learning games

① ② ③ ④ ⑤

d. Do simulations

① ② ③ ④ ⑤

e. Collect data using sensors or probes

① ② ③ ④ ⑤

f. Retrieve or exchange data

① ② ③ ④ ⑤

g. Solve problems using simulations

① ② ③ ④ ⑤

h. Take a test or quiz

① ② ③ ④ ⑤

Name of Participating Teacher____

Campus________________________________ Date___________________________

Current Grade(s)_________________________ Subject Area(s)_________________

APPENDIX D

Teacher Log

Please keep a running record of the time spent collaborating with your colleagues, researching your lesson topic, and planning your lesson outside of the scheduled meetings. In addition, be sure to note the activities and/or tasks you focused on during your independent times. Any information you provide will be confidential.

Name of Participating Teacher____

Middle
School_____________________________________GradeLevel_______________________

Date	*Activity/Task*	*Time*

APPENDIX E

Gear-Up Professional Development Evaluation Form
October 16, 2004

Name_______________________________________School_____________________

1. In viewing the activities and goals for the day, what did you experience and/or learn that you believe will facilitate your own teaching and learning of mathematics?

2. How do you think participation in lesson study will benefit you?

3. What do you think will be the challenges of lesson study?

4. Is there any part of lesson study that you are unclear about and if so, what are your burning questions?

APPENDIX F

Two-Hour Planning Session
Facilitator Guide

Roles: Researcher or Master's Graduate Student in the School of Education at the collaborating private university will serve as the recorder. "Knowledgeable Other" will serve as the facilitator and provide content support.

I. Planning the research lesson
   a. Note- Lesson study is most productive when educators build on the best existing lessons or approaches, rather than reinventing the wheel.
   b. Each member of the team shares what he/she has done in the past to teach the topic.
   c. The following list of questions will help to guide the planning of your research lesson:
      i. What do students currently understand about this topic?
      ii. What do we want them to understand at the end of the lesson?
      iii. What is the "drama" or sequence of questions and experiences that will propel students from their initial understanding to the desired understanding?
      iv. How will students respond to the questions and activities in the lesson? What problems and misconceptions will arise? How will the teacher use these ideas and misconceptions to advance the lesson?
      v. What will make this lesson motivating and meaningful to students?
      vi. What evidence about student learning, motivation, and behavior should be gathered in order to discuss the lesson and our larger research theme? What data collection forms are needed to do this?
   d. Be sure to determine how students will be assessed/evaluated. How will the team know if their goal was accomplished?
   e. Future plans
      i. Who will teach the research lesson?
      ii. When, where, and what time will the research lesson take place? **Remember, the research lesson should be taught no later than December 3rd. Also, remember that you will have your reflection session that same day from 4:00-6:00 or immediately following the research lesson.**
      iii. Who will need their class(es) covered?
      iv. Things to be done between now and the research lesson?
      v. Who will be responsible for typing up the lesson plan using the format and submitting it on *BlackBoard*?
      vi. Do you want to invite any other observers such as school level instructional specialist, principal or assistant principal, district mathematics specialist, etc.

II. Observation Training (last 30 minutes)

a. **Remember, the observation is not on or about the teacher. The observation is about the lesson.**
b. Brainstorm points or areas for observation such as:
    i. Individual students
    ii. Group interaction (focus group(s))
    iii. Questions asked by the teacher
    iv. Questions/statements from the students
    v. Visual aids (blackboard, overhead, etc) and/or materials used
c. Each observer then selects a specific role from the generated list.
d. As an observer, you will not be able to speak to the students or assist in ANYWAY. You are there to take notes on you observation. DO NOT INTERACT.
e. A seating chart for the class should be attached to the lesson plan in order to help identify students during the observation.

APPENDIX G

Research Lesson Observation Form

Name______________________________________ Date_______________

Middle School______________________________ Grade______________

Observation Focus____

Observation Notes:

APPENDIX H

Research Lesson and Reflection
Facilitator Guide

<u>Observation of Research Lesson</u>

1. Do not help students or otherwise interfere with the natural flow of the lesson.
2. Each observer should have a copy of the lesson plan, required material(s), and seating chart.
3. Collect data as requested in advance by the research lesson planning team, or focus your observation on the "points to notice" laid out in their lesson plan.
4. Observation forms attached

<u>Reflection of Research Lesson</u>

Remember the reflection is about the lesson and student understanding, not the teacher. Encourage teachers to take notes during the reflection session.

1. **Background Information from the Lesson Study Group Members**. The lesson study team members explain their goals for students (both lesson goals and long-term goals) and why they designed the lesson as they did. They describe changes made to the lesson design over time (several teams have met more than the one planning session). Note: the reflections from the lesson are not discussed at this point.
2. **The Instructor's Reflections**. The instructor describes her or his aims for today's lesson, comments on what went well and on any difficulties, and reflects on what was learned in planning and conducting today's lesson.
3. **Presentation and Discussion of Data from the Research Lesson.** Lesson study team members (followed by observers, if any) present and discuss data on student learning, engagement, and behavior from the research lesson and the larger unit of which it is a part. The data may include student work, a record of questions by the teacher and/or students, narrative records of all activities by particular children, record of the blackboard, etc., that have been agreed upon in advance. What do the data suggest about the students' progress on the lesson goals and goals for long-term development?
4. **General Discussion.** A free discussion period, facilitated by a moderator, may occur at this time. The focus is on student learning and development, and on how specific elements of lesson design promoted these. In other words, how do they know their objective was accomplished? Did the student's conceptually understand? The moderator may elicit and group comments, or designate particular themes for discussion, so that there is ordered discussed of key issues, rather than a "point-volleying session".
5. **Outside Commentator.** An invited outside commentator and/or the facilitator may discuss the lesson.

<u>Wrap-Up</u>

1. Using a number two pencil, teachers will need to complete the post Mathematics Teacher Survey.
2. Teachers will need to turn in their Teacher Logs.
3. Teachers will need to turn in all their observation notes.
4. A couple of teachers from each lesson study group will be randomly selected and asked to participate in a focus group that will involve a few questions pertaining to their experiences with lesson study. The focus group will be formed after the last research lesson (December 1st).
5. Groups will share their lesson study experience with all participants during the full-day of GEAR UP professional development next semester. Therefore, groups may want to start thinking about how they will “showcase their experience.”
6. **THANKS**. Please thank the instructor, planners, and attendees for their work to improve instruction.

APPENDIX I

Lesson Plan

Names:

Middle School: Grade:

Topic of the Lesson:

The Unit

Research Theme (or "Main Aim") of Lesson Study

Purpose (Goals/Objective)

Plan for the Research Lesson

Posing the Problem

Lesson Sequence (Questions, problems, and activities posed by the teacher)	**Anticipated Student Questions/Responses**	**Points for Observers to Notice**

Summary

In Class Evaluation/Assessment

Materials

Extension/Follow-Up

APPENDIX J

Madison Middle School Research Lesson Plan

Suggested Mathematics Lesson Plan

Names: Diann, Sally, Kay, and Vinson

Middle School: Madison Middle School Grade: 8

Topic of the Lesson: Just Face It
The Unit
Research Theme (or "Main Aim") of Lesson Study
We would like for students to process the qualities of being logical thinkers show compassionate and be productive citizens.

Purpose (Goals/Objective)
Our goal is for students to develop estimation skills in measurement using something they see everyday.

Plan for the Research Lesson
Posing the Problem

Lesson Sequence (Questions, problems, and activities posed by the teacher)	**Anticipated Student Questions/Responses**	**Points for Observers to Notice**
1. For which features were your estimates closest to actual Measurements? Furthest? Why do you think this happen? 2. What do you notice about the length of each eye and the bridge of the nose? As a class compare ratios of eye	What if the ruler is between two lines? Do you want length on top or height on top? How big is a centimeter? Is there a ratio that can be observed for one part of the face to the other?	Did the student estimate Measurement and evaluate reasonableness of results Did the student estimate measurement to solve application problems involving length including perimeter, circumference

length or create a scatter plot comparing the two. 3. What should student think about when estimating the height of their forehead, distance between bottom lip and tip of chin: width of smile? Compare ratios of these measurements Introduce the lesson: Do you know how you look? You are beautiful. Have a photocopy posted of a face in centimeters with two different dimensions. Today we are going to test your knowledge of the metric system by drawing a sketch of your face in centimeters. You will be divided into group of four. Each group will need a recorder, a person to draw, measurer, and the person whose face is being drawn. Pass out supplies.	Do different people have the same ratio of one part of the face to another part? How large is a centimeter**?**	Did student use proportional relationship in similar shapes to find missing measurement Did student identify and apply mathematics to everyday experiences and with other mathematics topics Did the student appear to understanding of appropriate length?

Student Investigation

The group presentation must include a written or drawn logic chart. Estimate in centimeters, draw the face accordingly to the estimations, and compare estimation to the actual drawing.

Students Problem Solving on Their Own

Review estimation results and apply them to real situations.

Summary

What was your favorite part of this lesson? Is there anything you still do not understand? What is that you understand now that you didn't understand in the beginning? Do you think centimeters will be the best measurement to use in this activity? After this activity, do you see the need for measuring correctly?

In Class Evaluation/Assessment

Have student to line up according to the circumference of their heads, from smallest to largest. Were most students' estimates below, close to, or above the true circumference of their head? Have student repeat this activity in inches. Were the estimates in inches better/worse than their estimations in centimeters? Why?

Materials

Face directions sheet, tape measure, scissors, tape, markers, ruler, butcher paper.

Extension/Follow-Up

APPENDIX K

Greenville Middle School Research Lesson Plan

Suggested Mathematics Lesson Plan

Names: Randy, Rachel, Gladys, and Ashton

Middle School: Greenville Middle School Grade: 7

Topic of the Lesson: Proportional Reasoning: Paper Clip Chains

The Unit
Research Theme (or "Main Aim") of Lesson Study

Purpose (Goals/Objective)

- Students will use two different sized paper clips to measure objects.
- Students will see the relationship between the large and small paper clips and determine the rate of small paper clips per large paper clips.
- Students will graph the relationship between the two sizes of paperclips by plotting points.
- Students will observe that the graph increases at a constant rate, and will be able to predict further lengths.

Plan for the Research Lesson
Posing the Problem

Lesson Sequence(Questions, problems, and activities posed by the teacher)	**Anticipated Student Questions/Responses**	**Points for Observers to Notice**
1. Teacher will introduce the lesson by posing questions about proportional relationships (i.e. Comparing Shaq's height/shoe size relationship to a child's height/shoe size). He/she will also give students an example of a non-proportional relationship (tiny body and huge head).	-students should respond by saying that the taller the person, the larger his/her foot should be.	
2. Teacher will hold up the two different sized paper clips. He/she will ask the students if they think that the paper clips are proportional.	-students may respond differently… some may think no because one is larger… some may say yes.	
3. Teacher will go over procedures of the activity: show students how to connect the paper clips, how to line them up to measure, how to record their data in the chart and on the graph.	-students may have trouble straightening the paper clips out.	
4. Students begin the activity. They will get a data sheet and determine how many small paper clips can add up to one large paper clip, and they will do the same with 4, 6, 8, 10, and 12 jumbo paper clips. They will record their number in the chart.	-What if only a little bit of a paper clip is left?	-See if students can estimate what a "part" of the paper clip would be instead of rounding to a whole paperclip.
5. Students will graph their results on the coordinate plane.	-Students may not understand which two columns from the chart to graph. They also may count boxes on the graph instead of lines and try to make a bar graph.	
6. Each group of students will have specific objects that they will measure with the large and small paper clips. They will record their measurements in the chart and plot their points in the graph.		
7. To see all of the groups' findings, students will plot their points using colored stickers on one large graph on the board		
8. Discuss with the students by asking the following questions:	-Students notice that the last column is the same number.	

1. What patterns do you see in the chart? 2. How many times bigger is the standard clip number than the big clip number? 3. What patterns do you see in the graph? 4. How do the patterns you found in the chart show up on the graph? 5. How could you use the patterns to determine the length of something in standard clips if you know its length in jumbo clips? 6. What are some types of measurement conversions that might be more practical than jumbo clips to standard clips?	-Students notice that the graph is a straight line. They will also notice that all of the groups' stickers line up in one line. -Students might say centimeters to meters or inches to feet.	-See what students can connect the chart information with the graph

Summary

Discussion above.

In Class Evaluation/Assessment

Use the charts/graphs to check data collecting and recording.
Use questions to assess what the students learned.
If there is still time, have the students extend the lesson by answering some TAKS related rate problems.

Materials

Jumbo paper clips (12 per group)
Standard paper clips (19 per group)
Data recording sheet for each student (WARNING: the one in the book does not have a graph that is large enough)

Extension/Follow-Up

Discuss and use other conversions in measurement. Also, review what a rate is.

APPENDIX L

Patton Middle School Research Lesson Plan

Names: Charles, Evan, Allison, Taylor, and Lauren

Middle School: Patton Middle School **Grade:** 6^{th} grade

Topic of Lesson: Introduce proportions and scale factor

The Unit

Research Theme of Lesson Study
-For students to develop effective communication skills and problem-solving skills to be marketable to businesses and to excel in society.

Purpose
-For students to understand the use of building proportions from ratios
-To have students use unconventional uses of measurement

Plan for the Research Lesson
Posing the Problem

Lesson Sequence (Questions, problems, and activities posed by the teacher)	**Anticipated Student Questions/Responses**	**Points for Observers to Notice**
1. Put the students into groups of three or four 2. Introduce the story to the students by presenting a PowerPoint 3. Explain the rules and instructions of the day to the students 4. Have the students start on the lesson 5. Have the students write their findings on a sheet of paper	Where is the ruler? How am I supposed to figure this out without a ruler? How do we figure this out? Can we write on this?	How students interact with each other The vocabulary that students are using when trying to solve the problem What the students decide to use to measure the foot of the monster

6. When the students have found the height of the monster, they need to tape on the wall how ever tall the monster is 7. Once all the groups have completed the lesson there will be a whole group discussion 8. The different groups will present their findings to the rest of the class	Can I take my shoe off? What do we use the butcher paper for? Where do we need to tape? How do we know, for sure, if we are right?	How students finally find the relationship of their foot to height and then apply that to the problem How the students decided if the answer was reasonable How the students decided to explain how they came up with the solution How the students came up with their solution

Summary

The students will have to determine how they can find the heights of the monsters using unconventional methods of measurement. The students will also have to discover the proportion of foot to body.

In Class Evaluation/Assessment

The students will tape their findings on the back wall of the classroom and if their response is reasonable then they have fulfilled the purpose of this lesson has been fulfilled

Materials

Masking tape
Blank pieces of butcher paper
Pencil
Paper
Seven paper paw prints of the giant's hand
In class evaluation

Extension/Follow-Up

Report your findings to the class during discussion

REFERENCES

AIMS Education Foundation. (2000). *Proportional reasoning.* Fresno, CA: Author.

AIMS Education Foundation. (1995). *Jaw breakers and heart thumpers*. Fresno, CA: Author.

Association for Supervision and Curriculum Development. (2003). *Comparing NAEP, TIMSS, and PISA in mathematics and science.* Retrieved October 4, 2005 from http://www.ascd.org

Atkins, J. M., & Black, P. (1997). Policy perils of international comparisons: The TIMSS case. *Phi Delta Kappan*, *79*, 22-28.

Atweh, B., Clarkson, P., Nebres, B. (2003). Mathematics education in international and global contexts. In A. J. Bishop, M. A. Clements, C. Keitel, J. Kilpatrick, & Leung, F. K. S. (Eds.), *Second international handbook on mathematics education: Part one* (pp. 185-229). Dordrecth, The Netherlands: Kluwer Academic Publishers.

Ball, D. L. (1990. March). The mathematical understandings that prospective teachers bring to teacher education. *The Elementary School Journal, 90(4),* 449-466.

Battista, M. T. (1999). The mathematical miseducation of America's youth: Ignoring research and scientific study in education. *Phi Delta Kappan, 80*, 425-433.

Ben-Peretz, M. (1990). *The teacher-curriculum encounter: Freeing teachers from the Tyranny of texts.* New York: State University of New York Press.

Berger, K. S. (1998). *The developing person through the life span* (2nd ed.), (pp. 31-53). New York: Worth Publishers, Inc.

Boaler, J. (2002). Open and closed mathematics: Student experiences and understandings. In J. Sowder & B. Schappelle (Eds.), *Lessons learned from research,* Reston, VA: National Council of Teachers of Mathematics, Inc.

Brewster, C. & Fager, J. (2000). *Increasing student engagement and motivation: From time-on-task to homework.* Retrieved October 21, 2005, from the Northwest Regional Educational Laboratory Web Site: http://www.nwrel.org/request/oct00/textonly.html

Brooks, J. G., & Brooks, M. G. (1993). *In search of understanding: The case for constructivist classrooms.* Alexandria, VA: Association for Supervision and Curriculum Development.

Burkhouse, B., Loftus, M., Sadowski, B., & Buzad, K. (2003). Thinking mathematics as professional development: Teacher perceptions and student achievement. U. S. Department of Education. Washington DC: Government Printing Office.

California State University, Sacramento, Institute for Education Reform. (1997, July). *Lessons in perspective: How culture shapes math instruction in Japan, Germany, and the United States.* Retrieved July 24, 2004, from the CSU Institute for Education Reform Web Site: http://www.csus.edu/ier/materials.html

Clarke, D. (1994). Ten key principles from research for the professional development of mathematics teachers. In D. B. Aichele & A. F. Coxford (Ed.), *Professional Development for Teachers of Mathematics.* New York: Macmillan.

Clarke, D. (2003). International comparative research in mathematics education. In A. J. Bishop, M. A. Clements, C. Keitel, J. Kilpatrick, & Leung, F. K. S. (Eds.), *Second international handbook on mathematics education: Part one* (pp. 143-184). Dordrecth, The Netherlands: Kluwer Academic Publishers.

Cooney, T. J., & Shealy, B. (1997). On understanding the structures of teachers' beliefs and their relationship to change. In E. Fennema & B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 87-109). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Curcio, F. R. (2002). *A user's guide to Japanese lesson study: Ideas for improving mathematics teaching.* Reston, VA: National Council of Teachers of Mathematics.

Dana, N. F., & Yendol-Silva, D. (2003). *The reflective educator's guide to classroom Research: Learning to teach and teaching to learn through practitioner inquiry*. Thousand Oaks, CA: Corwin Press, Inc.

Darling-Hammond, L. (1998). Teachers and teaching: Testing policy hypothesis from a national commission report. *Educational Researcher, 27(1),* 5-10.

Darling-Hammond, L. & Ball, D. L. (1998, November). Teaching for high standards: What policymakers need to know and be able to do. (CPRE Policy Briefs No. JRE-04). Philadelphia, PA: University of Pennsylvania, Consortium for Policy Research in Education.

Darling-Hammond, L., & Skyes, G. (1999). *Teaching as the learning profession: Handbook of policy and practice*. San Francisco: Jossey-Bass.

Dewey, J. (1938, 1998). *Experience and education: The 60th anniversary edition.* West Lafayette, Indiana: Kappa Delta Pi.

Education Development Center. (2002, December). *Massachusetts school teams see promise in Japanese professional development model.* Retrieved October 4, 2005, from http://main.edc.org/newsroom/features/lessonstudy.asp.

Edusoft. (n.d.) [software]. Retrieved October 2, 2005, from http://www.edusoft.com

Fay, J. T. (1979). Mathematics teaching today: Perspectives from three national surveys. *Mathematics Teacher, 12,* 490-504.

Fernandez, C., Cannon, J., & Chokshi, S. (2003). A US-Japan lesson study collaboration Reveals critical lenses for examining practice. *Teaching and Teacher Education, 19*, 171-185.

Fernandez, C. & Yoshida, M. (2004). *Lesson study: A Japanese approach to improving mathematics teaching and learning.* Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Fielding, N. G., & Lee, R. M. (1991). *Computer analysis and qualitative research.* Thousand Oaks, CA: Corwin Press, Inc.

Franke, M. L., Fennema, E., & Carpenter, T. P. (1997). Changing teachers: Interactions between beliefs and classroom practices. In E. Fennema & B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 255-282). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Gabler, I. A. & Schroeder, M. (2003). *Constructivist methods for the secondary classroom*, (pp. 3–34). Boston, MA: Pearson Education, Inc. & Allyn & Bacon.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38(4),* 915-945.

Gay, L. R., & Airasian, P. (2000). *Educational research: Competencies for analysis and application* (6th ed). Upper Saddle River, New Jersey: Prentice-Hall, Inc.

Gearhart, M., Sage, G. B., Seltzer, M., Schlackman, J., Ching, C. C., & Nasir, N. (1999). Opportunities to learn fractions in elementary mathematics classrooms. *Journal for Research in Mathematics Education, 30,* 286-315.

Germain-McCarthy, Y. (2001). *Bringing the NCTM standards to life: Exemplary practices for middle schools.* Larchmont, NY: Eye On Education.

GOALS 2000, H. R. 1804, 103rd Congress, (1994). Retrieved October 2, 2005, from http://www.ed.gov/legislatrion/GOALS2000/TheAct/index.html

Goldsmith, L. T. & Shifter, D. (1997). Understanding teachers in transition: Characteristics of a model for developing teachers. In E. Fennema & B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 19-54). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Goodlad, J. (1984). *A place called school.* New York: McGraw-Hill.

Greeno, J. G. (2003). Situative research relevant to standards for school mathematics. In J. Kilpatrick, W. G. Martin, & D. Schifter (Eds.), *A research companion to principles and standards for school mathematics* (pp. 304-332). Reston VA: National Council of Teachers of Mathematics, Inc.

Guskey, T. R. (2000). *Evaluating professional development.* Thousand Oaks, CA: Corwin Press, Inc.

Hart, K. (2000). Mathematics content and learning in the middle grades. In *Mathematics education in the middle grades: Teaching to meet the needs of middle grades learners and to maintain high expectations: Proceedings of a national convocation and action conferences.* Washington DC: National Academy Press.

Harwell, S. H. (2003). *Teacher professional development: It's not an event, it's a process*. Waco, TX: CORD.

Hiebert, J. (1999). Relationships between research and the NCTM standards. *Journal for Research in Mathematics Education, 30(1),* 3-19.

Hiebert, J. (2003). What research says about the NCTM standards. In J. Kilpartrick, W. G. Martin, & D. Schifter (Eds.), *A research companion to principles and standards for school mathematics* (pp. 5-23). Reston, VA: National Council of Teachers of Mathematics, Inc.

Hiebert, J., & Carpenter, T. P. (1992). Learning & teaching with understanding. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 65-97). New York: Macmillan.

Hill, H. C., & Ball, D. L. (2004). Learning mathematics for teaching: Results from California's mathematics professional development institutes. *Journal for Research in Mathematics Education, 35(5),* 330-351.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Education Research Journal*, *42(2),* 371-406.

Horizon Research Inc. (2003). 2000 National Survey of Science and Mathematics Education Mathematics Teacher Questionnaire. Retrieved August 5, 2004, from http://www.horizon-research.com/instruments/2000survey/tq-math.php

Johnson, K., & Blair, L. (1999). Teachers and students: The relationship at the heart of the matter. *Southwest Educational Development Laboratory New Sedletter*, *XI(2),* 3-6.

Kirk, R. E. (1999). *Statistics: An introduction* (4th ed.). Orlando, FL: Harcourt Brace & Co.

Kliebard, H. M. (1995). *The struggle for the American curriculum, 1893-1958* (2nd ed.), (pp. 1-25). New York: Routledge.

Knapp, M., & Sowder, J. (2004). Teacher quality and professional development. In F. K. Lester, Jr., & J. Ferrini-Mundy (Eds.), *Proceedings of the NCTM research catalyst conference* (pp. 177-186). Reston, VA: National Council of Teachers of Mathematics, Inc.

Kwakman, K. (2003). Factors affecting teachers' participation in professional learning activities. *Teaching and teacher education, 19,* 149-170.

Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. In T. P. Carpenter, J. A. Dossey, & J. L. Koehler (Eds.), *Classics in mathematics education research* (pp. 152-172). Reston VA: National Council of Teachers of Mathematics, Inc.

Lewis, C. (2000a, April). Lesson study: The core of Japanese professional development. Paper prepared for the American Educational Research Association meeting, New Orleans, LA.

Lewis, C. (2000b). *Can you lift 100 kilograms?* [Video].

Lewis, C. (2002a, January). Does lesson study have a future in the United States? *Nagoya Journal of Education and Human Development, 1,* 1-23.

Lewis, C. (2002b). *Lesson study: A handbook of teacher-led instructional change.* Philadelphia, PA: Research for Better Schools, Inc.

Lewis, C. (2003, Spring). The essential elements of lesson study. *Northwest Teacher, 4(3),* 6-8.

Lewis, C., Perry, R., & Hurd, J. (2004, February). A deeper look at lesson study. *Educational Leadership, 61(5),* 18-22.

Lewis, C., Perry, R., & Murata, A. (2003, April). *Lesson study and teachers' knowledge development: Collaboration critique of a research model and methods*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Lewis, C., Perry, R., & Murata, A. (2004, April). *What constitutes evidence of teachers' learning from lesson study?* Retrieved on August 24, 2004, from http://www.lessonresearch.net

Lewis, C., & Tsuchida, I. (1998, Winter). A lesson is like a swiftly flowing river. *American Educator*, (pp. 12-17, 50-52).

Linek, W. M., Raine, I. L., Fleener, C., Klakamp, K., & Fazio, M. (2003, November/December). The impact of shifting from how teachers teach to how children learn. *The Journal of Educational Research, 97(2),* 78-89.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (2003). Designing professional development for teachers of science and mathematics (2nd ed.). Thousand Oaks, CA: Corwin Press, Inc.

Lumsden, L. S. (1994). *Student motivation to learn* (ERIC Digest No. 92). Eugene, OR: ERIC Clearinghouse on Educational Management. (ERIC Document Reproduction Service No. ED 370 200)

Ma, L. (1999). *Knowing and teaching elementary mathematics.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Mac Iver, D. J., & Reuman, D. A. (1994). Giving their best: Grading and recognition practices that motivate students to work hard. *American Educator, 17(4),* 24-31.

Macomb Intermediate School District. (n.d.). Retrieved October 8, 2005, from http:www.misd.net/lessonstudy/about.htm

Manouchehri, A., & Goodman, T. (1998). Mathematics curriculum reform and teachers: Understanding the connection. *The Journal of Educational Research, 92(1),* 27-41.

Merriam, S. B. (1998). *Qualitative research and case study applications in education: Revised and expanded from case study research in education* (2nd ed.). San Francisco, CA: Jossey-Bass Publishers.

Mevarech, Z. R. (1999). Effects of metacognitive training embedded in cooperative settings on mathematical problem solving. *The Journal of Educational Research, 92(4),* 195-205.

Mewborn, D. S. (2003). Teaching, teachers' knowledge, and their professional development. In J. Kilpatrick, W. G. Martin, & D. Schifter (Eds.), *A research companion to principles and standards for school mathematics* (pp. 45-52). Reston VA: National Council of Teachers of Mathematics, Inc.

Morrissey, M., Cowan, D., Leo, T., & Blair, L. (1999). Renewing teachers, reforming schools through professional learning communities. *Southwest Educational Development Laboratory News Sedletter, 11(2),* 8-11.

Moses, R. P., & Cobb, C. E. (2001). *Radical equations: Civil rights from Mississippi to the algebra project.* Boston, Massachusetts: Beacon Press.

Moyer, P. S., & Packenham, E. D. (2001). The precollege program: A collaborative model of student enrichment and professional development in mathematics and science. In J. Rhoton & P. Bowers (Eds.), *Professional development leadership and the diverse learner,* (Library of Congress Catalog Card No. 00-110019, pp. 67-75). Arlington, VA: NSTA Press.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U. S. Government Printing Office.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Center for Education Statistics. (2004a). *Highlights from the trends in international mathematics and science study (TIMSS 2003).* Washington DC: U. S. Government Printing Office.

National Center for Education Statistics. (2004b). *The nation's report card.* Washington DC: U. S. Government Printing Office. Retrieved September 29, 2005, from http://nces.ed.gov/nationsreportcard/pdf

National Center for Education Statistics. (2005). *The nation's report card.* Washington DC: U. S. Government Printing Office. Retrieved November 1, 2005, from http://nces.ed.gov/nationsreportcard/pdf/main 2005/2006453.pdf

National Research Council. (2000). *How people learn: Brain, mind, experience, and school.* In J. D. Bransford, A. L. Brown, & R. R. Cocking (Eds.), Washington DC: National Academy Press.

National Research Council. (2001a). *Adding it up: Helping children learn mathematics.* In J. Kilpartrick, J. Swafford, & B. Findell (Eds), Washington, DC: National Academy Press.

National Research Council. (2001b). *Educating teachers of science, mathematics, and technology: New practices for the new millennium.* Washington, DC: National Academy Press.

National Research Council. (2002a). *Studying classroom teaching as a medium for professional development. Procedings of a U.S.-Japan workshop.* Hyman Bass, Zalman P. Usiskin, & Gail Burrill (Eds). Mathematical Sciences Education Board, Division of Behavioral and Social Sciences and Education, & U.S. National Commission on Mathematics Instruction, International Organizations Board. Washington DC: National Academy Press.

National Research Council (2002b). *Investigating the influence of standards: A framework for research for mathematics, science, and technology education.* Washington, DC: National Academy Press.

No Child Left Behind Act of 2001, H. R. 1 (S. R. 1), 107th Congress, 147 Cong. Rec. 1425 (2001). Retrieved December 15, 2003, from http://www.ed.gov/legislation/ESE A02/107-110. pdf.

O'Brian, T. C. (1999). Parrot math. *Phi Delta Kappan, 80,* 434-438.

Ohanian, S. (1999). *One size fits few: The folly of educational standards.* Portsmouth, NH: Heinemann.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer.* New York: Basic Books.

Patterson, T. (personal communication, October 5, 2005).

Perry, R., Lewis, C. & Akiba, M. (2002). *Lesson study in the San-Mateo-Foster city school district.* Paper presented at the 2002 annual meeting of the American Educational Research Association, New Orleans, LA. Retrieved July 21, 2004, from http://www.lessonresearch.net

Perry, R., & Lewis, C. (2003, April). *Teacher-Initiated lesson study in a northern California district.* Paper presented at the Annual Meeting of the American Educational Research Association. Retrieved July 21, 2004, from http://www.lessonresearch.net

Phillips, J. (2003, Spring). Powerful learning: Creating learning communities in urban school reform. *Journal of Curriculum and Supervision, 18(3),* 240-258.

Posner, G. J. (1995). *Analyzing the curriculum* (2nd Ed.), (pp. 44-67). New York: McGraw-Hill.

Reeves, D. B. (2001). *Crusade in the classroom: How George W. Bush's education reforms will affect your children, our school.* New York: Simon & Schuster.

Richards, L. (2002, March). *Using N6 in qualitative research.* Melbourne, Australia: QSR International Pty Ltd.

Richards, J., & von Glasersfeld, E. (1980). Jean Piaget, psychologist of epistemology: A discussion of Rotman's Jean Piaget: Psychologist of the real. *Journal for Research in Mathematics Education, 11,* 29-36.

Robitaille, D. F., & Travers, K. J. (1992). International studies of achievement in mathematics. In D. A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 687-709). New York: Macmillian.

Simon, M. A. (1997). Developing new models of mathematics teaching: An imperative for research on mathematics teacher development. In E. Fennema & B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 55-86). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Smith, M. S. (2001). *Practice-based professional development for teachers of mathematics.* Reston, VA: The National Council of Teachers of Mathematics, Inc.

Smith, T. M., Desimone, L. M., & Ueno, K. (2005, Spring). Highly qualified to do what? The relationship between NCLB teacher quality mandates and the use of reform-oriented instruction in middle school mathematics. *Educational Evaluation and Policy Analysis, 27(1),* 75-109.

SPSS Inc. (2005). [software]. Retrieved October 2, 2005 from http://www.spss.com

Stein, M. K. (2004). Studying the influence and impact of principles and standards for school mathematics. In F. K. Lester, Jr., & J. Ferrini-Mundy (Eds.), *Proceedings of the NCTM research catalyst conference* (pp. 83-95). Reston, VA: National Council of Teachers of Mathematics, Inc.

Stevenson, H. W., & Stigler, J. W. (1992). *The learning gap: Why our schools are failing and what we can learn from Japanese and Chinese education.* New York: Touchstone.

Stigler, J. W., & Hiebert, J. (1997). Understanding and improving classroom mathematics instruction: An overview of the TIMSS video study. *Phi Delta Kappan, 79,* 14-21.

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

Stigler, J. W., & Stevenson, H. W. (1991). How Asian teachers polish each lesson to perfection. *American Educator*, *15*, 12-47.

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

Tatsuoka, K. K., Corter, J. E., & Tatsuoka, C. (2004). Patterns of diagnosed mathematical content and process skills in TIMSS-R across a sample of 20 countries. *American Educational Research Journal, 41(4),* 901-926.

Texas Education Agency (TEA) (2003). *Public education information management system (PEIMS).* Retrieved October 2, 2005, from http://www.tea.state.tx.us

Thompson, A. G. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. *Educational Studies in Mathematics, 15,* 105-127.

U. S. Department of Education. (1996). *Pursuing excellence: A study of U. S. eighth grade mathematics and science teaching, learning, curriculum, and achievement in international context.* Washington DC: U. S. Government Printing Office.

U. S. Department of Education. (1998). *Promising practices: New ways to improve teacher quality*. Washington, DC: U. S. Government Printing Office.

U. S. Department of Education. (2001). *No child left behind.* Jessup, MD: Author.

U. S. Department of Education, National Center for Education Statistics. (2003, March). *Teaching mathematics in seven countries: Results from the TIMSS 1999 video study.* (NCES Publication No. 2003-013). Washington, DC. Government Printing Office.

Van de Walle, J. A. (2004). *Elementary and middle school mathematics: Teaching Developmentally.* Boston, MA: Pearson Education, Inc. & Allyn & Bacon.

Victoria University of Wellington. (n.d.). Retrieved October 5, 2005, from http://www.vuw.ac.nz/home/glossary

von Glasersfeld, E. (1981). An attentional model for the conceptual construction of units and number. *Journal for Research in Mathematics Education, 12,* 83-94.

Wagner, T. (1998). Change as collaborative inquiry: A constructivist methodology for reinventing schools. *Phi Delta Kappan, 79,* 512-517.

Wallace, J. D., Nesbit, C. R., & Newman, C. R. (2001). Bringing about school change: Professional development for teacher leaders. In J. Rhoton & P. Bowers (Eds.), *Professional Development Leadership and the Diverse Learner,* (Library of Congress Catalog Card No. 00-110019, pp. 37-47). Arlington, VA: NSTA Press.

Wang, A. H., Coleman, A. B., Coley, R. J., Phelps, R. P. (2003). Preparing teachers around the world. Princeton, NJ: Educational Testing Service.

Wang, J. & Lin, E. (2005, June/July). Comparative studies on U. S. and Chinese mathematics learning and the implications for standards-based mathematics teaching reform. *Educational Researcher, 34(5),* 3-13.

Watanabe, T. & Wang-Iverson, P. (2002). The Role of the Knowledgeable Others. Paper prepared for the Lesson Study conference. Retrieved on September 8, 2004, from http://www.rbs.org

Whicker, K. M., Bol, L., & Nunnery, J. A. (1997). Cooperative learning in the secondary mathematics classroom. *The Journal of Educational Research, 91(1),* 42-47.

Wilen, W., Bosse, M. I., Hutchison, J., & Kindsvatter, R. (2004). *Dynamics of effective teaching* (5th ed.). Boston, MA: Pearson Education, Inc. & Allyn & Bacon.

Wilkerson, T. (personal communication, September 16, 2004).

Willms, J. D. (2003). Student engagement at school: A sense of belonging and participation. Retrieved October 5, 2005, from the Organization for Economic Co-Operation and Development Web Site http://www.pisa.oced.org/dataoecd/42/35/33689437.pdf

Wilms, W. W. (2003, April). Altering the structure and culture of American public schools. *Phi Delta Kappan, 84(8),* 606-615.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of Research in Education, 24,* 173-209.

Windschitl, M. (1999). The challenges of sustaining a constructivist classroom culture. *Phi Delta Kappan, 80,* 751-755.

Wiske, M. S. (1998). *Teaching for understanding: Linking research with practice*. San Francisco, CA: Joseey-Bass.

Yoshida, M. (1999). Lesson study: An ethnographic investigation of school-based teacher development in Japan. Doctoral dissertation, University of Chicago.