THE IMPACT OF LESSON STUDY ON TEACHER PROFESSIONAL GROWTH USING THE DANIELSON FRAMEWORK FOR TEACHING: A MIXED METHODS STUDY

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AUTHORIZATION TO SUBMIT

DISSERTATION

This dissertation of Sheree Keller, submitted for the degree of Doctor of Philosophy in Educational Leadership with a major in Educational Leadership and titled "The Impact of Lesson Study on Teacher Professional Growth Using the Danielson Framework for Teaching: A Mixed Methods Study," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies.

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DEDICATION

I would like to dedicate this paper to my wonderful parents who taught me the value of education.

ABSTRACT

Lesson study is a model of effective professional development that originated in Japan and has become popular among math teachers worldwide in recent decades. Idaho math teachers have engaged in lesson study as a method of professional development for the past six years. Research is needed to determine the impact of lesson study on the professional growth of math teachers in Idaho. This study used a convergent mixed methods design to investigate the impact of lesson study on math teacher professional growth using the Danielson Framework for Teaching (FFT). The researcher used the Danielson FFT classroom observation instrument to identify the professional growth of lesson study participants. The researcher also used semi-structured teacher focus group interviews with teachers and one-on-one interviews with administrators to gain their perspectives regarding the impact of lesson study on math teacher professional growth. The data indicated lesson study with teachers had shifted math instruction from a traditional lecture-based approach to a more student-centered, discovery learning approach. Specifically, lesson study participants had created safe learning environments by normalizing error as part of the learning process. As a result, students were taking intellectual risks during class discussions and persevering in solving problems. Lesson study showed a positive impact on the professional growth of math teachers in the areas of question and discussion techniques, engaging students in learning, and using assessment during instruction. Results suggest lesson study can be used as an effective model of professional development for math teachers.

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Chapter I

Introduction

The importance of a highly effective educational system cannot be underestimated. Students need a quality education to be competitive in a global economy and for the advancement of society as a whole (Alam & Khan, 2019; National Commission on Excellence in Education, 1983; Stigler & Hiebert, 2009). Specifically, students need proficient math skills to be able to model and solve complex problems and to be successful in competitive industries (Danielson, 2007; Hattie et al., 2017; Schmidt, 2012). Proficient math skills are also necessary to make day-to-day health and financial decisions, interpret large volumes of statistical information, and to participate as a democratic citizen (Dewey, 1938; Schmidt, 2012). However, the achievement of US students on math assessments is low to average when compared to international students (Guglielmi & Brekke, 2017; Kolb, 2015; National Council of Teachers of Mathematics [NCTM], 2014; Schmidt, 2012; Stigler & Hiebert, 2009). This achievement gap of US math students has remained persistent since *A Nation at Risk* was published in 1983 (National Center for Education Statistics, n.d., 2018; National Commission on Excellence in Education, 1983; Schmidt, 2012; Stigler & Hiebert, 2009).

In 1989, the National Council of Teachers of Mathematics (NCTM) called for a common core of mathematics for all students that defined what US students need to know to succeed in college and the workforce (Anderson-Pence, 2015; NCTM, 2014; National Governors Association Center for Best Practices [NGA] & Council of Chief State School Officers [CCSSO], 2010; Schoenfeld, 2004; Steffe, 2017). The Common Core State Standards for Math (CCSSM) require a math education that is more rigorous, focused, and coherent to compete with high-performing countries (NGA & CCSSO, 2010). Despite these reform efforts and support for universal quality education, the achievement of US math students when compared to international students has seen gains, but remains below desired outcomes (Guglielmi & Brekke, 2017; National Center for Education Statistics, n.d.; Kolb, 2015; NCTM, 2014; Schmidt, 2012; Stigler & Hiebert, 2009).

The CCSSM require a shift from traditional teacher-centered classrooms to more student-centered classrooms where students engage in high-level tasks on a regular basis (Jentsch & Schlesinger, 2017; NCTM, 2014; Takahashi & McDougal, 2016). According to the standards, a high-quality math classroom is one where student-to-student discourse is initiated, and students defend and justify their thinking (Hattie et al., 2017; NCTM, 2014). This requires teachers to change their role from a transmitter of knowledge to facilitators of group work, student writing, and classroom discourse (Hattie et al., 2017; Herrera & Owens, 2001; Schoenfeld, 2004; Takahashi & McDougal, 2016). However, changing teacher practice is a particularly challenging endeavor since teaching is a cultural activity that follows accepted scripts and paradigms (Stigler & Hiebert, 2009). This underscores the need to support teacher change during reform efforts. This is especially true since teacher quality is the variable that has the greatest impact on student achievement, particularly with the underprivileged student population (Goldhaber, 2016; Schlesinger & Jentsch, 2016; Stigler & Hiebert, 2009). The quality of an education rests on the quality of its teachers and investing in teacher capacity can advance the entire school system (Alam & Khan, 2019; Desimone, 2009; Guskey, 2000; Shriki & Patkin, 2016; Vanassche & Kelchtermans, 2016).

Meaningful professional development experiences can provide teachers with the knowledge of content and pedagogy required to implement reform efforts (Desimone, 2009; Guskey, 2000; Shriki & Patkin, 2016). Specifically, teacher professional development programs have been shown to create changes in teacher practice (Blank et al., 2010; Darling-Hammond et al., 2017; Guskey, 2000, 2002; Lewis et al., 2019; Sandholtz et al., 2016; Yoon et al., 2007; Zambak et al., 2017). This can result in changes in teachers' knowledge of content and pedagogy (Alamri et al., 2018; Sandholtz et al., 2016; Schmidt, 2012), changes in teachers' beliefs regarding the process of learning (Arce et al., 2014; Guskey, 2002), or changes in teacher self-efficacy (Kaygisiz et al., 2018; Sandholtz et al., 2016; Zambak et al., 2017). Teachers' routines or instructional tools can also be changed through professional development (Dudley et al., 2019). The net effect is an alignment of teacher practice with the mission of a school or district (Kimbrel, 2018).

Traditionally, professional development has been provided through teacher in-service training such as courses, workshops, or seminars (Desimone, 2009; McElearney et al., 2019; Özdemir, 2019). However, the literature acknowledges the difficulty of changing teacher practice through in-service teacher training (Arce et al., 2014; Darling-Hammond et al., 2017; Guskey, 2000; Gutierez, 2015; Kennedy, 2016; Kimbrel, 2018; McElearney et al., 2019; Ottley et al., 2017; Sandholtz et al., 2016). The success of teacher in-service training may be hampered by the fact that it is often of short duration (Özdemir, 2019), does not take teacher needs into account (Aykaç & Yildirim, 2017; Moghaddam et al., 2015; NCTM, 2014; White, 2017), is not based on active learning (Moghaddam et al., 2015, Shriki & Patkin, 2016; White, 2017), and offers little opportunity for follow-up and support (Guskey, 2000). The outcome of these traditional models is that little of the content presented is transferred to teacher practice (McElearney et al., 2019). Teacher practice is more likely to change if the teachers are engaged in active learning activities in the context of their teaching assignments (Cajkler et al., 2015; Druken, 2015; Fernandez, 2002; Guskey, 2000; Lewis & Perry, 2017; McDonald, 2012; McElearney et al., 2019; Moghaddam et al., 2015; Shriki & Patin, 2016; White, 2017).

In 2001, the No Child Left Behind (NCLB) Act changed the culture of teacher professional development in the United States (No Child Left Behind [NCLB], 2002). The NCLB Act outlined new characteristics of effective teacher professional development – it was to be sustained and content-focused, aligned to content standards, aimed at increasing teachers' content and pedagogical knowledge, and regularly evaluated (NCLB, 2002). Since that time, there has been much research aimed at determining the effect of this new model of professional development on student achievement (Kettler & Reddy, 2019). The research has confirmed that professional development has the greatest impact on student achievement when it is content-focused, based on active learning, job-embedded, and of sufficient duration and timespan (Blank et al., 2007, 2010; Darling-Hammond et al., 2017; Desimone, 2009; Hammer, 2013; McElearney et al., 2019). Additionally, professional development has the greatest impact on student achievement when it combines subject matter content with pedagogical methods and includes ongoing support for teachers (Blank et al., 2010). The research also suggests that change in teacher practice is attainable if teachers can practice newly acquired skills in the context of their teaching position and have time to reflect on their practice (Aykaç & Yildirim, 2017; Darling-Hammond et al., 2017; McDonald, 2012; McElearney et al., 2019).

Lesson study is a method of professional development that is content-focused, collaborative, job-embedded, and sustained over time (Kolb, 2015; Schipper et al., 2018). Lesson study originated in Japan over 100 years ago and has become a popular form of teacher professional development worldwide in recent decades (Godfrey et al., 2018; Lewis et al., 2006, 2019; Makinae, 2010; Özdemir, 2019; Seleznyov, 2018; Takahashi & McDougal, 2016; Xu &

Pedder, 2015; Thinwiangthong et al., 2020). Lesson study is a particularly popular model of professional development in the United States among math educators (Godfrey et al., 2018; Lewis et al., 2019; NCTM, 2014; Takahashi & McDougal, 2016). The term lesson study is a literal translation of the term "jugyou kenyuu" that means "lesson study" in Japanese (Fernandez, 2002; Lewis et al., 2019; Lewis & Perry, 2017; Seleznyov, 2018; Takahashi & McDougal, 2016). Lesson Study allows teachers to construct knowledge in the context of their current teaching position (Druken, 2015; Lomibao, 2016; Özdemir, 2019). During the lesson study process, teachers work under the direction of a facilitator to identify a research theme based on desired student outcomes. Participants then collaboratively design, teach, observe, and reflect on a research lesson (Amador & Carter, 2018; Druken, 2015; Lewis et al., 2019; Lewis & Perry, 2017; Moghaddam et al., 2015; Takahashi & McDougal; 2016; Wright, 2009). Lesson study is theorized to change the culture of teaching since it creates a shared language about teaching and learning within the profession (Dudley et al., 2019 Fernandez, 2002; Lewis et al., 2019; Stigler & Hiebert, 2009; Takahashi and McDougal, 2016; Xu & Pedder, 2015).

Statement of the Problem

Substantial resources at the local, state, and federal level are spent every year on teacher professional development (Desimone, 2009). For example, in 2018, school districts in the United States spent $18 billion on teacher professional development (Horn & Goldstein, 2018). As a result, the outcomes of these programs need to be communicated to stakeholders (Alamri et al., 2018; Bill and Melinda Gates Foundation, 2013; Garcia et al., 2013; Godfrey et al., 2018; Guskey, 2000). Policymakers must be informed as to the effectiveness of these professional development efforts since they oversee the state and federal funds for the programs (Alamri et al., 2018; Blank et al., 2007; Garcia et al., 2013; King, 2013; Learning Mathematics for Teaching

Project, 2011; Sirait, 2016). A better understanding of the impact of various professional development models such as lesson study can inform education agencies on how to allocate future resources (Alamri et al., 2018; Blank et al., 2007; Garcia et al., 2013; King, 2013).

In the age of high-stakes accountability, schools and districts are under immense pressure to improve student achievement scores on standardized tests (Matthews, 2003). However, there is very limited causal evidence between lesson study and student achievement to guide program decisions (Gersten et al., 2014; Godfrey et al., 2018). This is due in part to the difficulty of measuring the effectiveness of professional development programs based on student achievement alone (Blank et al., 2007; Cajkler et al., 2015; Desimone, 2009; Dudley et al., 2019; Goldhaber, 2016). One of the challenges is the fact that many state assessments are norm-referenced, multiple choice tests (Hattie et al., 2017). These assessments may not be suited to measure more complex forms of learning such as critical thinking and problem solving that are required by the current standards (Danielson & McGreal, 2000; Lynch et al., 2017).

The CCSSM describe how students should engage with mathematical content to construct mathematical knowledge (Caprioara & Anghelide, 2016; Hattie et al., 2017; NGA & CCSSO, 2010; Strom et al., 2018). These are known as the Standards of Mathematical Practice (SMP) and can be applied at all grade levels. The SMPs include behaviors such as persevering in problem solving, justifying one's thinking, and critiquing the work of classmates (Hattie et al., 2017; NGA & CCSSO, 2010). One of the challenges of measuring professional development of math teachers specifically, is that standardized tests may not be valid measures of these complex student outcomes (Danielson & McGreal, 2000; Lynch et al., 2017). In addition, the research suggests that the most successful changes occur because of continuous improvement on the part of teachers and administrators through sustained effort. This change process takes time.

Therefore, it may not be possible to measure within a single year using quantitative standardized test data (Godfrey et al., 2018; Guskey, 2000).

When student achievement data is not attainable, the effectiveness of teacher professional development programs can be studied by examining the intervening changes in teacher practice (Alam & Khan, 2019; Alamri et al., 2018; Guskey, 2000; Shriki & Patkin, 2016; Vanassche & Kelchtermans, 2016). For instance, an increase in teacher mathematical content knowledge has been shown to have a positive effect on student achievement. Therefore, it can be used as a construct to measure instructional quality (Schmidt, 2012). Lesson study has been shown to have a positive effect on teachers' knowledge of content, pedagogy, and curriculum (Cajkler et al., 2015; Dudley et al., 2019; Godfrey et al., 2018; Lewis & Perry, 2017; Lomibao, 2016; Moghaddam et al., 2015; Murphy et al., 2017; Schipper et al., 2018; Xu & Pedder, 2015). The research also indicates that lesson study can lead to improved mathematical instruction since it allows teachers to become more aware of students' thinking processes (Amador & Carter, 2018; Cajkler et al., 2015; Celik & Guzel, 2020; Dudley et al., 2019; Godfrey et al., 2018; Lewis et al., 2006; Pehlivan & Güzel, 2020; Xu & Pedder; 2015).

Lesson study has also been shown to positively impact teacher self-efficacy, which has been correlated to an increase in the use of student-centered instructional strategies (Kaygisiz et al., 2018; Schipper et al., 2018; Xu & Pedder, 2015). However, much of the research surrounding lesson study is in the form of self-reported survey data or qualitative interviews (Druken, 2015; Dudley et al., 2019; Godfrey et al., 2018; Lomibao, 2016; Moghaddam et al., 2015; Murphy et al., 2017; Schipper et al., 2018). Teacher self-reported data may not be the most valid measure due to the gap that exists between teachers' perceptions of high-quality instruction and actual classroom practice (Munter, 2014). This makes it difficult to make an empirical argument for the effectiveness of lesson study to stakeholders. As a result, states and districts must use their own measures of effectiveness for lesson study programs (Gersten et al., 2014).

Many states annually measure instructional quality using classroom observation instruments as part of their teacher evaluation process. These classroom observation instruments have been shown to be stable predictors of instructional quality over time (Boston, 2012). The Danielson Framework for Teaching (FFT) is one of the most widely used classroom observation instruments in the United States (Garrett & Steinberg, 2015). The Danielson FFT is a non-content specific framework for high-quality instruction. It is based on constructivist learning theory and is designed to measure research-based teaching behaviors that have been shown to create higher levels of student achievement (Danielson, 2007; Danielson & McGreal, 2000; Kettler & Reddy, 2019; Milanowski, 2004; Reddy et al., 2019). The Danielson FFT assumes that good teaching provides students with the opportunity to construct their own understanding by actively engaging with the content and by engaging in classroom discourse (Danielson, 2007; Danielson & McGreal, 2000). This is consistent with the framework for high-quality math instruction outlined by the NCTM (NCTM, 2014). However, there is currently no research connecting the outcomes of lesson study programs to instructional quality as measured by the Danielson FFT. Using the FFT to assess lesson study programs would provide quantitative feedback to stakeholders that is aligned to statewide teacher evaluation practices.

Qualitative methods can add insight to the quantitative data collected (Creswell & Guetterman, 2019; Marshall & Rossman, 2016). There have been many qualitative studies conducted to determine teacher perceptions toward lesson study (Cajkler et al., 2015; Druken, 2015; Lomibao, 2016; Moghaddam et al., 2015; White, 2017). For example, interviews with teachers have shed light on how their participation in lesson study has affected their students' mathematical processes, and their students' dispositions toward math (Arce et al., 2014; Cajkler et al., 2015; Dudley et al., 2019; Godfrey et al., 2018; Moghaddam et al., 2015; Murphy et al., 2017).

High-quality math instruction requires students to take an active role in the learning (Hattie et al., 2017; NCTM, 2014; NGA & CCSSO, 2010; Schoenfeld, 2020). However, a gap exists in the literature surrounding teacher perceptions of how participating in lesson study has impacted their students' engagement in learning. In addition, the literature does not include perspectives from administrators of how lesson study has impacted the professional growth of their math teachers. There is a need to add the perceptions of administrators to the research since they have a unique perspective as evaluators of instructional quality (Danielson & McGreal, 2000).

Background

The Idaho legislature has acknowledged that mathematical skills are important for Idaho students to be successful academically and in the workplace (Idaho Math Initiative of 2014). In addition, the Idaho legislature has indicated that the achievement of Idaho's students in math needs to improve to meet the demands of the modern economy (Idaho Math Initiative of 2014). In 2014, the legislature passed the Idaho Math Initiative (IMI), which authorized the expenditure of $1.8 million to improve math education in Idaho (Idaho Math Initiative of 2014). This math initiative included authorization for the Idaho State Department of Education (ISDE) to provide high-quality professional development to K-12 math teachers. High-quality professional development was defined as being intensive, ongoing, connected to classroom practice, focused on student learning, and aligned with school improvement goals (Idaho Math Initiative of 2014).

The state of Idaho is divided into six educational regions based on culture, geography, and economic base. The IMI is executed in all six regions by four Idaho Regional Math Centers (IRMC). The math centers function within the four public universities in Idaho. The IRMC directors work closely with school and district leaders to customize professional development experiences to meet the unique needs of each region. These professional development opportunities include a range of services including but not limited to workshops, instructional coaching, video analysis, conferences, book study, and lesson study. The work of the IRMC supports the ISDE strategic plan to fully implement the Idaho math content standards. The benchmark for the strategic plan is to have 100% of 5^{th} and 10^{th} grade students scoring at or above the proficient level on the Idaho Standards Achievement Test by 2022 (Idaho State Department of Education, 2018).

Over the past five years, lesson study has become an increasingly popular method of professional development among math teachers in Regions II and IV in Idaho (R. Birnie, personal communication, April 22, 2020; R. Dent, personal communication, April 22, 2020). For example, during the 2015-16 school year, Region II started with a pilot lesson study group of eight K-5 teachers. By the 2019-2020 school year, the number of participants had grown to 73 K-12 math teachers (R. Dent, personal communication, April 22, 2020). Similarly, participation in lesson study in Region IV grew from 15 K-12 participants during the 2016-2017 school year to 100 K-12 participants during the 2019-2020 school year (R. Birnie, personal communication, April 22, 2020). The regional specialists have found that teachers generally choose to stay with the practice of lesson study once they have experienced it.

The regional specialists acknowledge the importance of measuring the impact that lesson study has on teacher practice and student outcomes (R. Birnie, personal communication, April

22, 2020; R. Dent, personal communication, April 22, 2020). Regions II and IV currently use teacher self-reported survey data to track teacher perceptions of how lesson study has affected their practice. The specialists have indicated that it would take additional resources to measure the effectiveness of lesson study more fully in their regions (R. Birnie, personal communication, April 22, 2020; R. Dent, personal communication, April 22, 2020).

Overview of Theoretical Framework

The CCSSM are predicated on the idea that learning is a cognitively active process (Herrera & Owens, 2001; Schoenfeld, 2004; Steffe, 2017). This is known as constructivist learning theory – it assumes people construct their own knowledge through the interaction between what they already know from their experiences with new content (Caprioara & Anghelide, 2016; Matthews, 2003; Powell & Kalina, 2009; Steffe, 2017; Ultanir, 2012). Constructivism can be further divided into cognitive and social constructivism (Powell & Kalina, 2009; Steffe, 2017). Cognitive constructivism derived from the work of Jean Piaget (1896-1980), who believed people construct knowledge through their experiences that are influenced by their stage of development (Bates, 2019; Lutz & Huitt, 2004; Matthews, 2003; Powell & Kalina, 2009; Ultanir, 2012). Social constructivism is derived from the work of Lev Vygotsky (1896-1934), who believed knowledge is constructed by the learner through social interactions (Bates, 2019; Lutz & Huitt, 2004; Matthews, 2003; Powell & Kalina, 2009; Steffe, 2017. John Dewey (1859-1952) also helped shape the ideas of constructivism by theorizing that knowledge is created by the learner as the result of individual and social experiences (Dewey, 1938; Lutz & Huitt, 2004; Matthews, 2003; Ultanir, 2012). Although these theories differ slightly, they all agree that knowledge must be intellectually constructed by the learner (Caprioara & Anghelide, 2016; Matthews, 2003). According to this theory, math students will construct meaning through the process of tackling real-world problems and applying their knowledge to authentic situations (Hattie et al., 2017; Ultanir, 2012). In addition, it is believed that mathematical knowledge can be constructed through social interaction and collaboration (Caprioara & Anghelide, 2016; Hattie et al., 2017; Schoenfeld, 2020).

In *Principles to Actions* (NCTM, 2014), the NCTM outlined eight Mathematics Teaching Practices (MTP) that provide a framework for high-quality math instruction (NCTM, 2014; Strom et al., 2018). Both cognitive and social constructivist instructional strategies are evidenced in the MTPs. For example, cognitive constructivism assumes teachers facilitate learning by encouraging students to form their own ideas and conclusions through exploration and inquiry (Caprioara & Anghelide, 2016; Herrera & Owens, 2001; Lutz & Huitt, 2004; Powell & Kalina, 2009; Ultanir, 2012). This can be seen in the MTPs – they describe student-centered math classrooms where teachers facilitate high-level tasks and support students as they grapple with mathematical concepts (NCTM, 2014; Strom et al., 2018). In addition, social constructivism is evidenced in the MTPs as they require teachers to promote socio-mathematical norms by asking students to make their thinking visible and challenge the thinking of their classmates (Hattie et al., 2017; NCTM, 2014; Strom et al., 2018). This establishes the validity of the MTPs as a measure of instructional quality since they capture what teachers are doing to facilitate learning in math classrooms (Alamri et al., 2018; Bill and Melinda Gates Foundation, 2013; Boston, 2012; Pianta & Hamre, 2009).

Research Questions

There is currently no research connecting the outcomes of lesson study programs to instructional quality as measured by the Danielson FFT. The Danielson FFT is one of the most widely used classroom observation tools in the Unites States and has been adopted by Idaho for in-service and pre-service teacher evaluations (Idaho Administrative Procedure Act, 2020). A better understanding of the impact of lesson study on instructional quality as described by the Danielson framework can inform state education agencies on teacher growth through professional development programs that are aligned to the state's teacher evaluation instrument. The following research questions offered guidance and focus for this study:

1. What is the impact of lesson study on math teachers' professional growth using the Danielson Framework for Teaching (FFT) classroom observation instrument?
2. What are math teachers' perceptions of the impact that lesson study has on their ability to engage students in learning as described by the Danielson FFT?
3. What are administrators' perceptions of the impact that lesson study has on their math teachers' professional growth as defined by the Danielson FFT classroom observation instrument?

Description of Terms

Classroom observation instrument. A classroom observation instrument is a tool used to collect data regarding teacher and student behaviors during a unit of instruction (Danielson & McGreal, 2000).

Cognitive constructivism. Cognitive constructivism purports that knowledge is created by the learner as they actively engage with the content (Caprioara & Anghelide, 2016).

Collaborative learning. Collaborative learning is a theory that suggests learning is an active experience shared with others through group discussions and activities (Aubrey & Riley, 2016).

Common Core State Standards of Math (CCSSM). A set of college and career readiness standards for math education in the United States. The CCSSM have been adopted by 45 states (NCTM, 2014).

Constructivism. Constructivism is a learning theory which supports the idea that people construct knowledge from the world around them (Aubrey & Riley, 2016).

Content knowledge. Content knowledge refers to the knowledge or skills that a teacher has relative to the particular subject they are teaching (Heck et al., 2019; Sandholtz et al., 2016; Schmidt, 2012; Wright, 2009).

Danielson framework for teaching (FFT). The Danielson framework for teaching is intended to define teacher responsibilities and behaviors that have been shown through research to promote improved student learning (Danielson, 2007).

Discovery Learning. Discovery learning is a type of instruction where students discover the material to be covered as they use their own prior knowledge to construct creative solutions to problems (Bates, 2019).

In-service training. In-service training is a form of professional development designed for teachers to develop new knowledge and skills. This is generally in the form of seminars, conference, or workshops (Aykaç & Yildirim, 2017; McDonald, 2012).

Job-embedded professional development. Job-embedded professional development refers to a form of teacher learning that takes place in the context of a teaching assignment (Guskey, 2000).

Knowledgeable other. A knowledgeable other has expertise on a topic and facilitates the lesson study process (Amador & Carter, 2018; Takahashi & McDougal, 2016).

Lesson study. Lesson study is a model of professional development. Lesson study is conducted in teams that create, plan, teach, and revise a research lesson (Lewis et al., 2019; Takahashi & McDougal, 2016; Xu & Pedder, 2015).

Mathematics teaching practices. The mathematics teaching practices provide a framework for teaching mathematics consisting of eight research-based practices (NCTM, 2014).

Math teacher. This study defined a math teacher as any K-12 teacher who teaches math lessons as part of their regular curriculum.

Pedagogical knowledge. Pedagogical knowledge refers to the knowledge or skills a teacher has regarding how to teach a particular subject. The focus of pedagogical knowledge is instructional strategies (Alamri et al., 2018; Merchie et al., 2018; Moghaddam et al., 2015; Wright, 2009).

Social constructivism. Social constructivism is founded on the theories of Lev Vygotsky, who believed humans create knowledge through social interaction, culture, and inner speech (Powell & Kalina, 2009).

Teacher professional development. Teacher professional development provides opportunities for professional growth to in-service teachers. The goal of teacher professional development programs is to increase student achievement by improving teachers' skills (Blank et al., 2007; Darling-Hammond et al., 2017; Desimone, 2009; Hammer, 2013; Yoon et al., 2007).

Research theme. A research theme is a component of Japanese lesson study that identifies the overarching goal of the research (Seleznyov, 2018; Takahashi & McDougal, 2016).

Research lesson. A research lesson is developed by a lesson study team with the focus on the effect of the lesson on student learning. A research lesson differs from a typical lesson in that the purpose is to provide teachers the opportunity to learn about instruction by forming and testing hypotheses regarding student learning in the context of the lesson (Cajkler et al., 2015; Dudley et al., 2019; Fernandez, 2002; Fujii, 2014; Gutierez, 2015; Lewis et al., 2006; Lomibao, 2016; Schipper et al., 2018; Takahashi & McDougal, 2016).

Teacher self-efficacy. Teacher self-efficacy relates to a teacher's belief in their ability to create desired student outcomes **(**Ireh & Bell, 2016; Kaygsiz et al., 2018; Lewis et al., 2019; Schipper et al., 2018; Zambak et al., 2017).

Standards-based education. Standards-based education is a type of instruction based on pre-determined college and career-ready standards (NCTM, 2014; Schoenfeld, 2004).

Standards for mathematical practice. The standards for mathematical practice provide a framework for learning math that consists of eight practices that outline how students are to engage with math and are applied at all grade levels (NGA & CCSSO, 2010).

List of Acronyms

The following list of acronyms are used frequently throughout this dissertation and are listed here for your reference.

AMP. Arizona Mathematics Partnership

CCSS. Common Core State Standards

CCSSM. Common Core State Standards for Math

CCSSO. Council of Chief State School Officers

CESSM. Curriculum and Evaluation Standards for School Mathematics

CLR. Collaborative Lesson Research

CSAS. Classroom Strategies Assessment System

ELA. English and Language Arts

ESEA. Elementary and Secondary Education Act

ESSA. Every Student Succeeds Act

IMI. Idaho Math Initiative

IRMC. Idaho Regional Math Centers

ISDE. Idaho State Department of Education

FFT. Framework for Teaching

KO. Knowledgeable Other

MET. Measures of Effective Teaching

MTP. Mathematical Teaching Practices

NCLB. No Child Left Behind

NCTM. National Council of Teachers of Mathematics

NGA. National Governors' Association

SMP. Standards for Mathematical Practice

TIMSS. Third International Mathematics and Science Study

ZPD. Zone of Proximal Development

Significance of the Study

The purpose of this study was to investigate the impact of lesson study on Idaho math teacher's professional growth as defined by the state-adopted teacher evaluation instrument. This study was significant because it clarified the impact lesson study can have on the quality of math education in terms of measurable teacher outcomes. This study provided information for educators, researchers, and policymakers relating to the field of professional development for math teachers. In this uncertain time of educational funding, this study could help inform policy makers on how to spend financial resources to provide professional development experiences that will align teacher practice to the state-adopted teacher evaluation instrument.

Overview of Research Methods

Mixed methods including quantitative and qualitative data can provide a clear view of the effects of professional development programs (Guskey, 2000). The purpose of this study was to investigate the impact of lesson study on math education in Idaho using measurable teacher outcomes. This study followed a convergent mixed methods design. The Danielson FFT classroom observation instrument was used to obtain quantitative data.

Qualitative descriptive methods guided the qualitative portion of the study. Qualitative description seeks to obtain insight on a narrow topic from the perspective of the participants (Colorafi & Evans, 2016; Neergaard et al., 2009). In qualitative descriptive studies, the researcher provides rich descriptions of participants' experiences using everyday language (Sandelowski, 2000; Willis et al., 2016). Qualitative measures for this study included semi-structured interviews with teacher focus groups and one-on-one semi-structured administrator interviews. Qualitative interviews helped the researcher understand the impact of lesson study from the perspectives of teachers and administrators (King, 2013).

In convergent mixed methods research, quantitative data and qualitative data are collected simultaneously (Creswell & Guetterman, 2019). In this study, the results of each were determined separately, then the findings were compared to see if the two approaches had similar or dissimilar findings. This approach allowed the researcher to draw on the strengths of quantitative and qualitative methods to triangulate the findings (Creswell & Guetterman, 2019; Marshall & Rossman, 2016). The result was greater insight into the empirical information regarding the teacher outcomes of lesson study, as well as a deeper understanding regarding the complex process of changing teacher practice (Creswell & Guetterman, 2019).

Summary

The CCSSM called for mathematics standards that defined the skills students in the United States need to succeed in college and the workforce (Anderson-Pence, 2015; NCTM, 2014; NGA & CCSSO, 2010; Schoenfeld, 2004; Steffe, 2017). Implementation of the CCSSM requires teachers to become facilitators of learning by providing students opportunities to construct knowledge through cognitively demanding experiences and by engaging in mathematical discourse (Hattie et al., 2017; Jentsch & Schlesinger, 2017; NCTM, 2014; Takahashi & McDougal, 2016). High-quality professional development can create the change in teacher practice required by the CCSSM. High-quality professional development is sustained, job-embedded, content-focused, collaborative, and provides opportunities for follow-up and support (Blank et al., 2010; Darling-Hammond et al., 2017; Hammer, 2013; Kennedy, 2016; Kolb, 2015; Schipper et al., 2018; Yoon et al., 2007). Lesson study is a high-quality model of professional development that originated in Japan and has become a popular model of professional development among math teachers worldwide (Godfrey et al., 2018; Lewis et al., 2006, 2019; Makinae, 2010; Özdemir, 2019; Seleznyov, 2018; Takahashi & McDougal, 2016; Thinwiangthong et al., 2020; Xu & Pedder, 2015).

In the age of educational accountability, stakeholders need to be informed regarding the effectiveness of professional development programs (Alamri et al., 2018; Bill and Melinda Gates Foundation, 2013; Garcia et al., 2013; Godfrey et al., 2018; Guskey, 2000). However, it is not always possible to measure the effectiveness of a professional development program using student achievement data alone (Blank et al., 2007; Cajkler et al., 2015; Desimone, 2009; Dudley et al., 2019; Goldhaber, 2016). The purpose of this study was to determine the impact of a lesson study program on the professional growth of math teachers in Idaho.

The next chapter summarizes the history of math education in the United States and the evolution of the common core standards. It also discusses the research behind the characteristics of high-quality professional development and lesson study specifically as a form of professional development for math teachers. It concludes with a discussion of how classroom observation instruments can be used to measure instructional quality as defined by constructivist views of teaching and learning.

Chapter II

Review of Literature

Introduction

Proficient math skills are necessary to be competitive in a global economy (Danielson, 2007; Schmidt, 2012; Stigler & Hiebert, 2009). In fact, proficiency in math can be considered as a gatekeeper to our modern society since most top paying college majors are math related (Hattie et al., 2017). However, in recent decades, international math assessments have shown a deficit in the performance of US students (Guglielmi & Brekke, 2017; National Center for Education Statistics, n.d.; Kolb, 2015; NCTM, 2014; Schmidt, 2012; Stigler & Hiebert, 2009). As a result, many states adopted the Common Core State Standards for Math (CCSSM) to increase the rigor of math instruction. The CCSSM require math teachers to transition from traditional transmitters of knowledge to facilitators of mathematical experiences (Hattie et al., 2017; Jentsch & Schlesinger, 2017; NCTM, 2014; Strom et al., 2018). There is a need to support math teachers in their implementation of the CCSSM through professional development opportunities (Pehlivan & Güzel, 2020). The Idaho state legislature passed the Idaho Math Initiative (IMI) in 2014 that authorized the Idaho State Department of Education (ISDE) to provide high-quality professional development to math teachers (Idaho Math Initiative of 2014). Lesson study is a model of ongoing professional development that has become popular in Idaho under the IMI since 2016 (R. Birnie, personal communication, April 22, 2020; R. Dent, personal communication, April 22, 2020). This chapter reviews the literature surrounding lesson study and its impact on the professional development of math teachers.

The literature acknowledges the need to inform stakeholders regarding the effectiveness of professional development programs to inform the allocation of future resources (Alamri et al., 2018; Bill and Melinda Gates Foundation, 2013; Garcia et al., 2013; Godfrey et al., 2018; Guskey, 2000). There is a need in Idaho to inform state and local agencies regarding the IMI expenditure on teacher professional development efforts including lesson study (C. Beals, personal communication, April 22, 2020). Classroom observation instruments are one method used to measure the impact of teacher professional development programs (Danielson, 2007; Lynch et al., 2017; Schlesinger & Jentsch, 2016). The Danielson Framework for Teaching (FFT) is one of the most widely used classroom observation tools in the United States (Garrett & Steinberg, 2015). This chapter provides a brief history of teacher evaluation practices in the Unites States as well as the research surrounding the reliability and validity of the Danielson FFT. A better understanding of the impact of lesson study on teachers' implementation of research-based practices using the Danielson FFT can inform state education agencies on teacher professional growth through lesson study programs.

This study used constructivism as a theoretical framework to show the relationship between lesson study, intended teacher outcomes, the Danielson FFT, and desired student outcomes. This chapter reviews the major contributors to constructivist learning theory and presents an argument for the alignment of math teacher outcomes and the Danielson FFT using a constructivist lens.

Math Education

History of Math Education in the United States

As recently as the 1890s, a high school education in the United States was a privilege of the elite – fewer than seven percent of the population was enrolled by the age of 14 (Schoenfeld, 2004). High school math curriculum included algebra, geometry, and trigonometry. The remainder of the population learned just enough math to prepare them for predetermined social roles (Kolb, 2015; Schoenfeld, 2004). Around 1920, social justice educators called for equal educational opportunities for all students (Schoenfeld, 2004). This created contention between the progressive educators and those who believed the role of schooling was to train the working class (Steffe, 2017).

After WWII, there was growing concern over the state of US education in math and science when compared to the Russians (Herrera & Owens, 2001; Schoenfeld, 2004; Steffe, 2017). The launch of *Sputnik* in 1957 caused the United States to be perceived as being behind in the field of math and technology (Steffe, 2017). Mathematics education emerged as a field of study shortly thereafter in the 1960s. Prior to that, writing on mathematics teaching and curriculum was done by mathematicians and philosophers (Schoenfeld, 2020). As a result, traditional instruction gave way to a more problem-solving and discovery approach to teaching math (Herrera & Owens, 2001; Steffe, 2017). This era, known as the modern mathematics movement of the 1960s, included theory and logic instruction (Steffe, 2017). However, during this time, assessment efforts failed to show the impact of the new approach on student achievement (Schoenfeld, 2004; Steffe, 2017). As a result, the 1970s were met with a back-to-the-basics approach to math education with more emphasis on computation and manipulation, and less emphasis on discovery, discourse, and problem solving (Herrera & Owens, 2001; Schoenfeld, 2004; Steffe, 2017). During this era, international math assessments showed that US students were behind students in other developed countries (Stigler & Hiebert, 2009).

In 1983, the publication of *A Nation at Risk* created a public sentiment of a national crisis in math education much like that in response to *Sputnik* (Herrera & Owens, 2001; National Commission on Excellence in Education, 1983; Steffe, 2017). At the time of its publication, the performance of US math students continued to fall behind those of other advanced countries and there was an increasing trend of US high school graduates not being prepared for work or college (National Commission on Excellence in Education, 1983). In response, the National Commission on Excellence (1983) conducted an 18-month study of education in the United States and made recommendations to improve the quality of math instruction based on their findings. The recommendations included strengthening the graduation requirements for US students, more rigorous content in textbooks, more time devoted to learning content, and more support for math and science teachers. In addition, the commission recommended implementing rigorous standards that could be measured by state and local standardized tests (National Commission on Excellence in Education, 1983).

In 1989, the National Council of Teachers of Mathematics (NCTM), the National Governors Association Center for Best Practices (NGA), and the Council of Chief State School Officers (CCSSO) published the *Curriculum and Evaluation Standards for School Mathematics* that called for equity in instruction and a common core of mathematics for all high school students (Anderson-Pence, 2015; NCTM, 2014; Schoenfeld, 2004). One of the biggest differences between this and the previous movements in math education is that the NCTM's standards were intended to apply to all students, not just the college bound (Herrera & Owens, 2001).

Providing a high-quality, standards-based education to all students in the United States has been met with challenges. Achievement gaps have emerged between certain subgroups of students (Heise, 2017). Over the years, the federal government has enacted legislation to provide resources to these vulnerable student populations. For example, in 1965, congress passed the Elementary and Secondary Education Act (ESEA), which allocated federal funds to disadvantaged students. In addition, the Rehabilitation Act of 1973 directed funds toward students with special needs, and Title IX passed in 1972 ensured that students are not discriminated against based on gender (Heise, 2017).

In 2001, congress passed the No Child Left Behind Act (NCLB) with the intent to close the achievement gap between various subgroups of students (NCLB, 2002). What was unique about NCLB is that it applied to all schools in the United States regardless of the constituency of their students (Heise, 2017). The NCLB required states to meet annual yearly progress of student academic achievement in core subjects in order to receive federal funding. This created the need for accountability-based systems for schools and districts based on large-scale assessments. The NCLB required states to develop their own assessments and submit them for federal approval. However, by 2012, 80% of US public schools were predicted to fail to meet the required annual yearly progress (Heise, 2017). In 2011, the Secretary of Education offered waivers to states to avoid federal sanctions in exchange for an agreement to adopt the Common Core State Standards (Heise, 2017). The standards were intended to raise the quality of focus, rigor, and coherence of math standards nation-wide (Schmidt, 2012). The standards were based on constructivist principles, which assumes that the learning is a cognitively active process (Schoenfeld, 2004). The new math standards called for students to engage in authentic math tasks, participate in math discourse, and use a variety of models and representations while solving real-world problems (Anderson-Pence, 2015; Herrera & Owens, 2001).

By the early 2000s, every state had adopted its own learning standards along with its own definition of proficiency. This created a lack of standardization among the states. The Common Core State Standards were designed to create a more standardized approach to math curriculum by defining what needed to be taught for US students to succeed in college and the workforce (NGA & CCSSO, 2010). The CCSSM drew on international models of math instruction, as well as research surrounding students' math knowledge and how that develops over time (NGA & CCSSO, 2010). This resulted in a math education that was more rigorous, focused, and coherent (NGA & CCSSO, 2010). By 2013, 43 states had adopted the standards including Idaho, which adopted the standards in 2011 (Heise, 2017). In March 2022, the Idaho legislature voted to replace the CCSSM with Idaho's own version of the math content standards. The changes included rewording the standards for simpler verbiage, vertical alignment of the concept strands, and age-appropriate descriptions of the standards of mathematical practice for each grade level (Idaho State Department of Education, 2022).

In 2015, congress passed the Every Student Succeeds Act (ESSA), which replaced the NCLB act. The ESSA permitted states that had previously adopted the common core state standards to withdraw or replace the standards. This gave states more control over their accountability systems (Heise, 2017). Despite these reform efforts and support for universal quality education, the achievement of US math students when compared to international students has seen gains, but remains below desired outcomes (Guglielmi & Brekke, 2017; National Center for Education Statistics, n.d.; Kolb, 2015; NCTM, 2014; Schmidt, 2012; Stigler & Hiebert, 2009).

Standards-Based Math Instruction

Throughout history, mathematics instruction has been influenced by educational psychology. For example, in 1900, Edward Thorndike performed a famous cat experiment that led to the birth of behaviorist learning theory. The theory purported that education should be founded on skills and habits (Steffe, 2017). Around 1919, John Dewey began the progressive educational movement, which promoted the idea that education should be centered on experiences (Steffe, 2017). Later, in 1952, Jean Piaget published *The Child's Perception of*

Number, which promoted the use of concrete examples and manipulatives (Herrera & Owens, 2001). In 1966, Jerome Bruner devised three levels of mathematical development – enactive (hands-on), iconic (diagrams), and symbolic (numerals), which influenced math education by promoting the idea that children of all ages could construct ideas about math through investigation and discovery (Herrera & Owens, 2001). The 1970s and 1980s saw an increased knowledge base about teaching and learning in what has come to be known as the cognitive revolution (Schoenfeld, 2004). The standards movement began shortly thereafter in 1989 with the publication of the *Curriculum and Evaluation Standards for School Mathematics* (CESSM). These standards were based on a constructivist view of learning (Steffe, 2017). Part of the constructivist agenda was to provide mathematics for all – a social agenda which assumed that all students could learn the math outlined in the CESSM standards (Steffe, 2017).

As a result, mathematics instruction began to be based on constructivist principles that include discovery learning with an emphasis on problem-solving strategies. The current CCSSM are based on these constructivist theories of learning (NGA & CCSSO, 2010). The CCSSM contain Standards for Mathematical Practice (SMP) that outline how students are to engage with mathematical content and are applied at all grade levels. Under the CCSSM, students are to:

- make sense of problems and persevere in solving them,
- reason abstractly and quantitatively,
- construct viable arguments and critique the reasoning of others,
- model with mathematics,
- use appropriate tools strategically,
- attend to precision,
- look for and make sense of structure, and

- look for and express regularity in repeated reasoning (NGA & CCSSO, 2010).

Accomplishing these mathematical standards requires a shift from traditional teacher-centered instruction to more student-centered instruction. They require students to engage in high-level tasks on a regular basis (Jentsch & Schlesinger, 2017; NCTM, 2014; Takahashi & McDougal, 2016). According to these standards, a high-quality math classroom is one where student discourse is initiated, students carry the conversation themselves, and students defend and justify their thinking (Hattie et al., 2017; NCTM, 2014; Schoenfeld, 2020; Strom et al., 2018). Central to high-quality instruction is the establishment of learning goals that are connected to the big mathematical ideas (Hattie et al., 2017; NCTM, 2014; Schoenfeld, 2020). In high-quality classrooms, problem solving is more about developing mathematical practices of mind such as modeling with representations rather than getting the right answer (Schoenfeld, 2020). In addition, students are given opportunities to make their thinking visible (Hattie et al., 2017; Jentsch & Schlesinger, 2017; NCTM, 2014). High-quality math instruction also includes purposeful questions and requires students to reflect on their answers and those of their classmates (Hattie et al., 2017; NCTM, 2014). High-quality teachers create learning experiences that develop students' conceptual understanding through explanations and examples. Lessons follow logical progressions from exploration to discussion to reasoning (Jentsch & Schlesinger, 2017; NCTM, 2014; Strom et al., 2018). Students in high-quality classrooms strive to continuously improve and are trained to persevere in problem solving (Hattie et al., 2017; NCTM, 2014; Schoenfeld, 2020; Strom et al., 2018). Lastly, high-quality teachers use assessment as an ongoing process to inform instruction, adjusting as necessary (NCTM, 2014; Thinwiangthong et al., 2020). This requires students to learn to assess and recognize the quality of their own work and that of their classmates (Hattie et al., 2017; NCTM, 2014). In sum, teachers are asked to change their role from a transmitter of knowledge to a facilitator of group work, student writing, and classroom discourse (Hattie et al., 2017; Herrera & Owens, 2001; Schoenfeld, 2004; Takahashi & McDougal; 2016). This requires teachers to have a thorough knowledge of content and pedagogy (Blank et al., 2007; Herrera & Owens, 2001; Takahashi & McDougal, 2016).

Although most states have adopted the CCSSM, they do not inform teachers about what actions to take at the classroom level (Kolb, 2015; NCTM, 2014). For example, a recent study investigated the perspectives of preservice and in-service teachers regarding the CCSSM (Kruse et al., 2017). Participants in this study attended a two-hour professional development session regarding the teachers' role in promoting students' engagement with the SMPs. The entry survey indicated that prior to the professional development experience, the participants lacked familiarity with the SMPs and were not able to identify teacher behaviors that would promote the SMPs (Kruse et al., 2017). Following the experience, the participants were more aware of the teachers' role when promoting the SMPs, but they still had questions regarding the meaning of the SMPs and how teachers can foster them (Kruse et al., 2017). This underscores the need to provide math teachers with ongoing professional development opportunities that will increase their knowledge of content and pedagogy (Blank et al., 2007; Kolb, 2015; Kruse et al., 2017; NCTM, 2014; Schmidt, 2012; Takahashi & McDougal, 2016).

Standards-Based Math Instruction in Idaho

Idaho joined the Common Core State Standards initiative in June 2009. The intent was to join the other states in developing a more rigorous college- and career-ready curriculum. The standards were implemented in Idaho classrooms during the 2013-14 school year (Idaho State Department of Education, 2011). In March 2022, the Idaho legislature voted to replace the Common Core standards. Highlights of the changes to the standards included mastery learning targets for mathematical facts, less complex verbiage, and standards based on age appropriateness at each grade level (Idaho State Department of Education, 2022). This required the state department to write descriptions of the SMPs for each grade level to describe what problem-solving activities could look like at each grade level. Although Idaho revised its math standards in 2022, they are still based on the CCSSM and require students to engage with mathematical content as described by the SMPs.

Teacher Professional Development

Traditional Models

Traditionally, professional development for teachers followed a one-stop model. For instance, during the 1950s and 1960s, teachers typically attended in-service meetings where they sat as passive recipients of knowledge while listening to an expert speaker (McDonald, 2012). During the 1970s, administrators began to take the lead role in furthering the education of their staff, and the term staff development became more commonplace. Staff development efforts were generally provided in the form of one-size-fits-all workshops, seminars, or conferences (Desimone, 2009). However, the literature acknowledges the difficulty of changing teacher practice using these traditional models (Arce et al., 2014; Darling-Hammond et al., 2017; Desimone, 2009; Guskey, 2002; Gutierez, 2015; Kennedy, 2016; Kimbrel, 2018; McElearney et al., 2019; Ottley et al., 2017; Stigler & Hiebert, 2009). Transferring in-service training to classroom practice may be hampered by the fact that it not only requires teachers to adopt new methods, but to abandon teaching methods they have been practicing for extended periods of time (Gutierez, 2015; Kennedy, 2016). These teaching methods are generally a product of the country or culture in which they are practiced and are therefore very stable and resistant to change (Stigler & Hiebert, 2009).

Another limitation of traditional teacher in-service training is that it is often top-down, prescriptive, and may not be based on teachers' immediate needs (Alamri et al., 2018; Lewis & Perry, 2017; Moghaddam et al., 2015; Shriki & Patkin, 2016; White, 2017). For example, a study in Turkey showed that teachers felt the in-service training they received did not meet their needs, and their opinions were not taken into consideration when designing the training programs (Aykaç & Yildirim, 2017). The teachers also considered the in-service training to be too focused on theory, with insufficient time for practice and application (Aykaç & Yildirim, 2017). This demonstrates that a teacher's motivation towards professional learning can be negatively affected if it is mandatory (Kennedy, 2016) or not aligned to teachers' professional goals (Aykaç & Yildirim, 2017; Vanassche & Kelchtermans, 2016). The literature acknowledges that professional development is more effective when the teachers are invited to be active partners in their professional growth (Kimbrel, 2018; NCTM, 2014).

Traditional workshops, seminars, and conferences do not afford time for teachers to engage in the content, and do not provide the ongoing follow-up and support needed to create a persistent change in teacher practice (Arce et al., 2014; Blank et al., 2010; Darling-Hammond et al., 2017; Guskey, 2002; Hammer, 2013; Murphy et al., 2017; Ottley et al., 2017; Sandholtz et al., 2016; Yoon et al., 2007). For example, a study in Puerto Rico compared two groups of middle school science teachers who participated in two different models of professional development (Arce et al., 2014). Both groups attended a government-sponsored professional development course including a two-week summer workshop, monthly daylong workshops, and visits by their professors. However, only the first group received follow-up and support by participating in a community of learners in their teaching environment. The study found that the group of teachers who participated in the follow-up learning activities were more successful in changing their approach to teaching and learning (Arce et al., 2014).

Teacher attitudes and beliefs can also affect the transfer of in-service training to teacher practice (Anderson-Pence, 2015; Hammer, 2013; Kennedy, 2016; Kimbrel, 2018; McElearney et al., 2019). A change in teacher practice is dependent upon teachers' buy-in to educational reform efforts and their willingness to try new strategies (Hammer, 2013). Guskey (2000) argued that teachers must see the effect that a new teaching strategy has on student achievement before they will change their beliefs towards the strategy.

Another barrier to the transfer of in-service training is that it may not be conducted in the context of the teacher's classroom (Guskey, 2000; Özdemir, 2019). Many workshops, seminars, and conferences are provided outside the school or district where a teacher works and may not be directly correlated to their curriculum. The research indicates that teacher training is more effective when it is aligned to the curriculum and conducted in the context of the teacher's classroom (Blank et al., 2010; Darling-Hammond et al., 2017; Fernandez, 2002; Hammer, 2013; Yoon et al., 2007).

High-Quality Professional Development

In 1983, the United States published *A Nation at Risk*, which paved the way for standards-based education and requirements for high-quality teachers (National Commission on Excellence in Education, 1983). This created the need for models of teacher professional development that would have lasting effects on teacher practice (Blank et al., 2007; Desimone, 2009; McDonald, 2012; Stigler & Hiebert, 2009; Yoon et al., 2007). In 2001, the NCLB required that teachers receive high-quality professional development that was:

- sustained and content focused,

- aligned to content standards and student achievement,
- focused on teachers' content knowledge,
- focused on research-based instructional strategies, and
- evaluated for teacher outcomes and student achievement (NCLB, 2002).

This model of professional development differs from traditional models in that it is a more transformational model of professional learning where participants are invited to engage with the content actively (Blank et al., 2007; Danielson & McGreal, 2000; Darling-Hammond et al., 2017; Desimone, 2009; Hammer, 2013; McDonald, 2012; McElearney et al., 2019). Active learning in professional development means allowing teachers to plan, practice, and discuss the new material. Active learning is most effective when provided to teachers who share the same content, grade, or school – this facilitates job-embedded learning (Hammer, 2013). Also, teachers must receive feedback on the impact the change is having on their students' learning. This feedback can be in the form of student achievement, student involvement, or student behavior. The literature suggests that showing teachers the impact of their new practice on student learning will motivate them to continue to implement the new strategies (Guskey, 2002, 2016).

Over the past few decades, researchers have sought to determine the effect of high-quality professional development on student achievement. For example, Yoon et al. (2007) reviewed 1,300 studies conducted between 1986-2006 to determine the effect of high-quality professional development on elementary student achievement in math, science, and English. Yoon and colleagues synthesized the results of qualifying studies to determine the effect of high-quality professional development. The average effect size across the studies was 0.54, showing that high-quality professional development has a moderately positive effect on student achievement (Yoon et al., 2007).

A follow-up study by Blank et al. (2010) investigated the effect content-focused professional development had on student achievement in math and science. Blank and colleagues screened over 400 studies and synthesized 16 qualifying studies. The results showed that content-specific professional development had a positive effect on student outcomes, with a slightly higher effect size for elementary teachers than secondary teachers (Blank et al., 2010). The most effective professional development programs combined subject matter content with pedagogical methods. Other effective practices included ongoing support for teachers from mentors and colleagues, activities for reinforcement of learning, and assistance with implementation (Blank et al., 2010).

In 2013, the West Virginia Department of Education published a report that built on these previous studies with the intent to identify additional characteristics of high-quality professional development for teachers (Hammer, 2013). This report acknowledged the complexity of creating change through professional development programs due to the contextual factors surrounding its implementation, such as teacher attitudes about professional learning, organizational structures, and the professional environment. The report concluded that professional development should be focused on content knowledge beginning with the prior knowledge of the teachers. In addition, professional development should contain active learning experiences by providing opportunities for teachers to plan, practice, and discuss the new material (Hammer, 2013). Duration and time span were also shown to impact the results of professional development positively. However, the literature did not agree as to the amount of time required to create change in teacher practice. The range of time in the literature was from 30-80 contact hours with duration ranging from one to three years (Hammer, 2013).

A more recent meta-analysis conducted by Darling-Hammond et al. (2017) synthesized empirical studies of professional development programs that showed a significant positive effect on student achievement. The study identified common elements across 35 studies and made recommendations to inform policymakers on future professional development endeavors. The study identified the characteristics of professional development that had the most significant impact on student achievement as follows:

- content focus
- active learning based on adult-learning theory
- collaborative learning
- modeling of effective practice
- feedback and reflection
- sustained duration
- expert support (Darling-Hammond et al., 2017).

These findings share many characteristics with those outlined in NCLB (NCLB, 2002). Although the need for sustained, content-focused training remains the same, this study suggests the addition of collaborative, job-embedded, and active learning to the professional development model (Darling-Hammond et al., 2017). There is also evidence that professional development should include principles of adult learning such as building on previous learning experiences, providing choice in learning activities, and providing time for reflection (Danielson & McGreal, 2000; Darling-Hammond et al., 2017). These findings are consistent with a study of teachers in Northern Ireland, which reported that teachers found collaborative research had a more significant impact on their practice than the traditional workshop model (McElearney et al., 2019).

Improved student achievement is the goal of any professional development program, but it can be difficult to measure its effectiveness based on student achievement alone (Blank et al., 2007; Desimone, 2009; Guskey, 2000). One reason is that student learning can be influenced by factors outside the teachers' control, such as students' home environments, curriculum, school leadership, students' capacity to learn, and school organization (Danielson & McGreal, 2000; Guskey, 2000; Kettler & Reddy, 2019). In addition, it can be difficult to find valid measures of student learning. Traditionally, schools have relied on norm-referenced multiple-choice tests (Hattie et al., 2017). However, multiple choice tests may not be a valid measure of more complex learning standards such as critical thinking or problem solving (Danielson & McGreal, 2000). When student outcomes are not available, the effectiveness of professional development programs can be evaluated by measuring changes in teacher practice (Desimone, 2009; Guskey, 2000; Lewis et al., 2019; Lewis & Perry, 2017; Merchie et al., 2018). The research shows that high-quality professional development efforts can create changes in teacher content and pedagogical knowledge (Alamri et al., 2018; Sandholtz et al., 2016), teacher beliefs and attitudes (Arce et al., 2014; Guskey, 2000; Heck et al., 2019; Zambak et al., 2017), teacher self-efficacy (Sandholtz et al., 2016; Zambak et al., 2017), and teacher professional routines (Dudley et al., 2019). These intervening changes to teacher practice have been shown to have a positive effect on student outcomes (Alam & Khan, 2019; Arce et al., 2014; Zambak et al., 2017). This could be because instructional quality is the variable that has the greatest impact on student achievement (Danielson & McGreal, 2000; Guskey, 2000; Schlesinger & Jentsch, 2016; Schmidt, 2012; Stigler & Hiebert, 2009).

Lesson Study

In the 1960's, the first international mathematics study compared student achievement in math of 12-year-olds across 11 countries (Baker, 2007). The results of the study indicated that US students scored significantly lower than those in other countries (Stigler & Hiebert, 2009). In the 1980's, a second international study showed little improvement for US students. This was not surprising since methods for teaching math in the United States remained mostly unchanged during the 21st century (Stigler & Hiebert, 2009). Changing teaching practice is a particularly challenging endeavor since teaching techniques depend on the culture in which they are practiced (Schmidt, 2012; Takahashi & McDougal, 2016). This is due in part to the fact that teachers often adopt the teaching practices they observed when they were students (Stigler & Hiebert, 2009). In addition, teaching is a cultural activity that follows accepted scripts and paradigms that are very stable over time (Stigler & Hiebert, 2009). Educational reforms in the United States have sought major changes over short periods of time by training teachers in research-based strategies, but this is often provided outside the context of their day-to-practice and may not address the cultural shifts necessary to create systemic change (Stigler & Hiebert, 2009).

In 1993, the Third International Mathematics and Science Study (TIMSS) project began with the intent of comparing mathematical teaching methods between the United States, Germany, and Japan (Stigler & Hiebert, 2009). During the TIMSS project, eighth-grade math classrooms across the three countries were video recorded. The researchers analyzed the data to determine the difference in teaching techniques between the cultures. Japanese teaching methods in math were of particular interest since Japanese students have traditionally scored high on math achievement tests (Stigler & Hiebert, 2009). The study found that American math students spent a significant amount of time in isolated drill practice when compared to Japanese students. By comparison, the Japanese students not only engaged in isolated drill practice but spent as much time solving complex math problems and discussing mathematical concepts. The data suggested that in the United States, mathematics is taught as a set of procedures for solving problems. In this paradigm, the role of the teacher is to provide opportunities for students to engage in error-free practice. By contrast, Japanese teachers tend to encourage students to struggle in the face of difficulty as they determine possible approaches to solving a problem (Stigler & Hiebert, 2009). In 2010, the CCSSM outlined Standards for Mathematical Practices (SMP) for US students, which place a greater emphasis on mathematical thinking, perseverance in problem solving, and communication skills (NCTM, 2014; NGA & CCSSO, 2010; Takahashi & McDougal, 2016).

The TIMSS project revealed that not only was math pedagogy different between the Unites States and Japan, but so was its method of teacher professional development (Stigler & Hiebert, 2009). In Japan, *jugyou kenkyuu* (translated "lesson study") has been a widely used model of teacher professional development since the 1870's (Lewis & Perry, 2017; Özdemir, 2019; Schipper et al., 2018; Seleznyov, 2018; Takahashi & McDougal, 2016). Lesson study is a cyclical model of professional development where teachers work collaboratively in an iterative cycle to design, deliver, and improve research lessons (Druken, 2015; Lewis et al., 2019; Moghaddam et al., 2015; Wright, 2009). Almost all Japanese teachers are involved in at least one lesson study cycle during the school year (Lewis et al., 2019; Özdemir, 2019). Lesson study is a form of sustained, job-embedded professional development that has been shown to create the transformational changes necessary to improve math instruction (Amador & Carter, 2018; Lewis et al., 2006, 2019; Lewis & Perry, 2017; NCTM, 2014; Takahashi & McDougal, 2016; Xu & Pedder, 2015).

History of Lesson Study

In 1872, the Meiji government created a new school system in Japan. The purpose was to allow Japan to become more like Western countries. Japanese teacher prep schools invited American teachers to come and share their teaching methods. The object lesson was one of the teaching methods that was introduced to Japan by the Americans. It was based on the Pestalozzian theory which assumes that students learn by intuition as they observe a phenomenon and create a mental concept. In order to train pre-service teachers to use this new technique, the Japanese created the criticism lesson. In a criticism lesson, each preservice teacher taught a lesson in front of their peers followed by receiving constructive criticism. This method was eventually expanded as a method of professional development for in-service teachers. This was the beginning of the lesson study process for Japanese teachers. In this model, they learned to collaboratively design, teach, reflect, and critique research lessons (Makinae, 2010).

This evolved into the practice of lesson study, where teachers work in teams under the direction of a facilitator to design, teach, and revise a research lesson with the goal of developing high-quality mathematics instruction (Lewis et al., 2019; Takahashi & McDougal; 2016). The lesson study cycle includes collaborative studying, planning, teaching, and observing a lesson with a focus on student learning (Amador & Carter, 2018; Lewis & Perry, 2017). The research lesson can be revised and retaught to improve instruction and learning (Schipper et al., 2018). The term “lesson study” has evolved into an umbrella term that describes several variations and adaptations (Xu & Pedder, 2015). For example, in Japan, lesson study is used at the national level to disseminate pedagogical information and at the local level as a method of professional development. There is also a variation known as “design study” that facilitates research between a university and classroom teachers. In Hong Kong and Sweden, “learning study” is practiced, which provides a framework for teachers to study the variation in students’ progress and learning. In China, “action education” is practiced, which focuses on the development of a single teacher. These global variations of lesson study all provide practical contexts for teachers to learn and improve their practice in the classroom (Xu & Pedder, 2015).

Lesson Study has become an increasing popular method of teacher professional development world-wide since the publication of Stigler and Hiebert's (2009) landmark study (Godfrey et al., 2018; Lewis et al., 2006, 2019; Thinwiangthong et al., 2020; Xu & Pedder, 2015). Specifically, lesson study has become increasingly popular in English-speaking countries such as the United Kingdom and the United States (Dudley et al., 2019; Seleznyov, 2018). One of the first reports of the implementation of lesson study in the United States was in the San Mateo-Foster City School District in California during the 2000-01 school year. The district was looking for a sustained, teacher-led model of professional development to improve classroom instruction (Lewis et al., 2006). Initial volunteers for the study included 26 instructional coaches and teachers. The following fall, the entire staff at one of the elementary schools decided to engage in lesson study, and the practice was still being implemented at the time of publishing the article (Lewis et al., 2006).

Japanese Lesson Study

Lesson study has been used as a form of professional development in Japan for over 100 years (Makinae, 2010; Seleznyov, 2018; Takahashi & McDougal, 2016). Lesson study has been shown to improve teaching practice and change the culture of teaching (Celik & Guzel, 2020; Dudley et al., 2019 Fernandez, 2002; Lewis et al., 2019; Pehlivan & Güzel, 2020; Stigler & Hiebert, 2009; Takahashi and McDonald, 2016; Thinwiangthong et al., 2020; Xu & Pedder, 2015). The lesson study process can be described by a four-phase cycle: study, plan, teach, and reflect (Druken, 2015; Fernandez, 2002; Lewis et al., 2019; Moghaddam et al., 2015; Schipper et al., 2018; Stigler & Hiebert, 2009; Takahashi & McDougal, 2016). The following describes each phase of the lesson study process.

Study Phase. The first phase of lesson study is the study phase where a team is formed and a research theme is selected (Lewis et al., 2019; Lewis & Perry, 2017). The research theme is determined by comparing the long-term goals of the school or district with current student learning, or by considering topics that are difficult to teach or difficult for students to learn (Fernandez, 2002; Fujii, 2014; Seleznyov, 2018; Stigler & Hiebert, 2009). Once the research theme is determined, the team members learn as much as they can about the topic. In Japan, this process is called "*kyouzai kenyuu*" which translated means a "study of teaching materials" (Fernandez, 2002; Lewis et al., 2019, Seleznyov, 2018; Takahashi & McDougal, 2016). Takahashi and McDougal (2016) compared this process to a literature review where participants investigate the research topic including a review of standards and curriculum, possible resources and materials, instructional methods, and anticipated student misconceptions. For example, elementary teachers in Iran selected the addition of two one-digit numbers in story-problems as the theme for one of their research lessons (Moghaddam et al., 2015).

Plan Phase. Once the study team has learned as much as they can about the research topic, team members identify the student learning objectives for the research lesson (Lewis et al., 2019; Lewis & Perry, 2017; Takahashi & McDougal, 2016). A research lesson differs from a typical lesson in that the purpose is to create learning opportunities for the teachers by allowing them to make and test hypotheses about student learning (Amador et al., 2019; Takahashi & McDougal, 2016). This shifts the role of the teacher to learner and researcher. The lesson objectives are determined by considering the gap that exists between where the students currently are and where they would like them to be in the future (Lewis et al., 2019; Takahashi & McDougal, 2016). From this, the team can determine an intended learning trajectory for their students. An essential component of lesson study is for teachers to make hypotheses about the student responses they expect to see when the lesson is taught (Seleznyov, 2018; Takahashi & McDougal, 2016). Team members then make a data collection plan for what student behavior to observe and how to collect the data during the lesson. This phase of the lesson study cycle is facilitated by what the Japanese call a Knowledgeable Other (KO). The job of the KO is to guide the planning process and provide feedback on the research lesson and data collection plan (Lewis et al., 2019; Lomibao, 2016; Seleznyov, 2018; Takahashi & McDougal, 2016). This is consistent with what the literature indicates about teacher preferences with professional development – studies have shown that teachers prefer professional development that is provided by trainers who are experts in their field (Aykaç & Yildirim, 2017; Darling-Hammond et al., 2017; McDonald, 2012).

Teach Phase. One member of the lesson study team teaches the research lesson in their classroom while the other members observe and collect the data (Fernandez, 2002; Lewis et al., 2019; Lewis & Perry, 2017; Seleznyov, 2018). The purpose of the observation is to determine the impact of the lesson on the students' learning relative to the research theme – not to evaluate the teacher's performance (Seleznyov, 2018; Takahashi & McDougal, 2016). In some situations, the research lesson may be taught as a mock-up lesson with the other team members serving as students before it is taught as a live research lesson (Lewis et al., 2019). The mock run-through gives the team opportunities to try instructional strategies, anticipate student misconceptions, and determine specific points in the lesson for data collection. A pre-lesson discussion among the team members along with an observation instrument can help the team members focus on what data to collect during the observation (Amador et al., 2019; Lewis et al., 2019).

Reflect Phase. After the research lesson has been taught, the lesson study team meets to debrief and collaboratively discuss the evidence collected and reflect on what they have learned from the lesson (Fernandez, 2002; Lewis & Perry, 2017; Seleznyov, 2018; Stigler & Hiebert, 2009; Takahashi & McDougal, 2016). Data from the observation is compiled and analyzed. Team members can test their hypotheses about student learning against the data collected. Through collaborative reflection, the team discusses possible revisions to the lesson to improve student learning. A KO is used during this phase to facilitate the discussion and to help make connections between the findings and the research theme (Lewis et al., 2019). At the end of the cycle, team members discuss ideas for future study in subsequent learning cycles.

The literature is mixed as to whether the research lesson should be revised and retaught (Seleznyov, 2018). Some literature suggests revising the research lesson and reteaching it to a different group of students (Fernandez, 2002; Lewis et al., 2019). However, others argue that this puts too much emphasis on lesson study as a means to create a perfect lesson plan rather than as a learning opportunity for teachers (Takahashi & McDougal, 2016). In addition, teaching the revised lesson to a new group of students undermines the fact that the lesson was designed for a specific group of students including their anticipated responses (Fujii, 2014). Part of the confusion may be due to the fact that in Japan, when lesson study is used at the national level, a research lesson may be taught and revised before being taught before a large audience. However, when lesson study is used at the district level as a form of teacher professional development, the research lesson is not generally retaught (Fujii, 2014; Takahashi & McDougal, 2016).

Implementation Outside Japan

Lesson study has been used outside Japan since the 1990s (Lewis et al., 2006; Takahashi & McDougal, 2016). Studies have found that when lesson study is practiced outside Japan, some of the key elements are modified or left out, which can minimize its impact (Fujii, 2014; Godfrey et al., 2018; Seleznyov, 2018). For example, a seminal study by Fujii (2014) investigated the implementation of lesson study in Africa after African educators had attended lesson study seminars in Japan. The results showed that there were misconceptions about Japanese lesson study among African educators (Fujii, 2014). For example, in Malawi, researchers found lesson study was treated more like a workshop. The workshops in Malawi did not begin with a research question – a critical component of Japanese lesson study (Fujii, 2014). In addition, teachers in Uganda and Malawi tended to view the research lesson plan as a script that needed to be followed exactly. In contrast, Japanese teachers view lesson plans as flexible, which allows them to make adjustments according to student needs. The Japanese approach to mathematics instruction, which involves structured problem solving, was also implemented differently in Africa. In Japan, the bulk of the ideas originate from the students and the student voice is heard throughout the lesson. However, in Malawi, the teachers posed a problem to solve, but did not anticipate or focus on student responses (Fujii, 2014). Researchers in this study found that in Africa, the participants focused their post-lesson discussion on the teacher who had taught the lesson and not the teaching and learning (Fujii, 2014).

A literature review by Seleznyov (2018) found similar results regarding the implementation of lesson study in English speaking countries. The review included an investigation of English language research on lesson study in academic journals between 2005 and 2015. The study found that in general, English-speaking countries diluted the Japanese process (Godfrey et al., 2018; Seleznyov, 2018). Specifically, the review found that one third of the studies did not identify a research theme. The study also found that the majority of studies did not engage teachers in the study of materials and did not include a KO. In addition, the majority of English language applications of lesson study involved the reteaching of the research lesson with the focus of creating a perfect lesson plan. This is consistent with the findings of Takahashi and McDougal (2016), which found that many lesson study programs in the United States mistakenly focus on the creation of a perfect lesson plan as opposed to creating knowledge regarding teaching and learning.

Cultural and systemic differences may be the reason for some of the challenges of implementing lesson study in English-speaking countries. A study of an early implementation of lesson study in New York and New Jersey revealed some challenges faced by American teachers (Fernandez, 2002). All teachers in the study were nervous about teaching in front of their peers. This may be due to the fact that in the Unites States, teachers are not used to critique and need to develop dispositions for receiving feedback (Moghaddam et al., 2015). In addition, there is a national curriculum in Japan that facilitates a common language for teachers when engaging in lesson study. The teachers in the New York and New Jersey study also seemed challenged by having to move past lesson study as an opportunity to analyze their teaching rather than an opportunity to learn about their teaching (Fernandez, 2002). For example, one of the groups chose the promotion of critical thinking by encouraging students to ask rich questions as their research theme. The group struggled to create a research question, design a classroom experiment, and decide on what data to collect. In the end, the group focused on simply planning the lesson. By focusing on revising and reteaching the lesson, the teachers lost sight of lesson study as an inquiry into teaching (Fernandez, 2002).

Takahashi and McDougal (2016) outlined a form of lesson study known as Collaborative Lesson Research (CLR), which contains the critical elements of Japanese lesson study. The elements include:

- a research purpose

- a study of teaching materials
- a research proposal
- a live research lesson
- knowledgeable others
- sharing of results (Takahashi & McDougal, 2016).

The purpose of CLR is to facilitate groups of teachers working together to learn about teaching and learning. In CLR there is no requirement to reteach a research lesson after it has been observed. This is to keep teachers focused on collaborative learning rather than on the development of a perfect lesson plan (Takahashi & McDougal, 2016).

Impact of Lesson Study

The impact of lesson study has been the subject of much research since its worldwide implementation in the 1990's. The results from the research regarding the impact of lesson study on student achievement using assessments has been mixed (Godfrey et al., 2018 et al.; Lewis & Perry 2017; Murphy et al., 2017). One study in the United States showed a significant positive effect on student knowledge of fractions (Lewis & Perry, 2017). For the study, teachers were divided into three groups: lesson study participants supported by a resource kit, participants free to choose their own form of professional development, and lesson study participants not supported by a resource kit. Student mathematical knowledge of fractions was measured using a pre/post-test assessment. The post-test showed a statistically significant positive effect for the lesson study participants who were supported by a resource kit (Lewis & Perry, 2017). In another study, schools in London conducted three lesson study cycles during an academic year in order to develop and share experiences with a trial version of a new curriculum. The researchers studied the impact on student achievement by looking at standardized test data for the 11-year-olds. The students of the teachers who had participated in lesson study showed a four percent advantage over the students at the non-lesson study schools (Dudley et al., 2019). A subsequent randomized control trial studied the effect of lesson study on student achievement over a two-year period (Murphy et al., 2017). In this study, researchers recruited 182 elementary schools in England and randomly assigned them to either a treatment or control group. The control group engaged in business as usual, and the treatment group engaged in lesson study. Performance data between the control and treatment groups was compared using a national standardized test. The results indicated no significant difference in student achievement in either math or reading at the conclusion of the intervention even after comparing the effect among subgroups including free lunch, gender, and minority status (Murphy et al., 2017).

It can be challenging to determine the effect of lesson study based on student achievement alone (Cajkler et al., 2015; Guskey, 2000). This is due in part to the fact that improved student outcomes are the result of additional factors such as parent knowledge, leadership, and curriculum (Guskey, 2000). In addition, lesson study is designed to create small transformational changes to instruction over a considerable amount of time, making it difficult to measure improvements in student learning in one academic year (Cajkler et al., 2015; Dudley et al., 2019; Godfrey et al., 2018; Guskey, 2000; Lewis et al., 2006; Murphy et al., 2017; Xu & Pedder, 2015). The literature suggests alternate methods such as measuring student achievement over long periods of time (Murphy et al., 2017), measuring student achievement relative to a specific learning target (Godfrey et al., 2018), or measuring other student outcomes such as student engagement (Xu & Pedder, 2015). Lesson study has been shown to positively impact qualitative student outcomes such as student engagement and mathematical discourse, which are known to improve student achievement (Godfrey et al., 2018).

The impact of lesson study can also be investigated by studying the resulting changes in teacher practice since teachers have been shown to have the most direct effect on student outcomes (Alam & Khan, 2019; Goldhaber, 2016; Guskey, 2000; Schmidt, 2012; Shriki & Patkin, 2016; Vanassche & Kelchtermans, 2016). The research indicates that lesson study increases teachers' knowledge of content, pedagogy, and curriculum (Cajkler et al., 2015; Dudley et al., 2019; Godfrey et al., 2018; Lewis et al., 2006, 2019; Lewis & Perry, 2017; Lomibao, 2016; Moghaddam et al., 2015; Murphy et al., 2017; Schipper et al., 2018; Xu & Pedder, 2015). The research also shows that lesson study has a positive impact on student learning by providing the opportunity for teachers to become more familiar with the student learning process (Cajkler et al., 2015; Xu & Pedder; 2015). Specifically, lesson study provides opportunities for teachers to focus on student thinking in the classroom environment, and to reflect on student thinking in professional discussions (Amador & Carter, 2018; Celik & Guzel, 2020; Dudley et al., 2019; Lewis et al., 2006; Pehlivan & Güzel, 2020). This focus on student thinking has been shown to increase teachers' confidence in their students' capacity to engage in interactive, discovery, and problem-solving approaches to learning (Anderson-Pence, 2015; Cajkler et al., 2015; Dudley et al., 2019; Lewis & Perry, 2017). This leads to teachers being more comfortable with constructivist mathematical instruction (Godfrey et al., 2018; Xu & Pedder, 2015). Lesson study has also been shown to improve teachers' practice of formative assessment. This is accomplished by encouraging high-order, open-ended questions that facilitate observation of students' progress towards the learning target (Thinwiangthong et al., 2020). Lesson study has also been shown to positively impact teacher self-efficacy, which is correlated to an increase in the use of student-centered instructional strategies (Schipper et al., 2018; Xu & Pedder, 2015).

This is aligned with the intended student outcomes under the CCSSM (Kaygisiz et al., 2018; NGA & CCSSO, 2010).

Instructional Quality Measures

In 2001, congress passed the NCLB Act with the intent to close the achievement gap between various subgroups of students (NCLB, 2002). The NCLB required states to meet annual yearly progress of student academic achievement in core subjects in order to receive federal funding. This put pressure on districts to raise student test scores (Kettler & Reddy, 2019; Milanowski, 2004; Sirait, 2016). However, there are several complications with using student achievement data to measure the effectiveness of educational programs. For example, traditional norm-referenced, multiple choice achievement tests may not be suited to measure complex forms of learning such as critical thinking and problem solving (Danielson, 2007; Danielson & McGreal, 2000; Lynch et al., 2017). In addition, student outcomes can be affected by external factors such as parent involvement, student capacity to learn, and curriculum (Guskey, 2000). These factors can impact the level of bias in such measures (Danielson, 2007; Danielson & McGreal, 2000; Guskey, 2000; Kettler & Reddy, 2019). In addition, two-thirds of teachers work in non-tested grades or subjects (Bacher-Hicks et al., 2017). Teacher classroom assessments could be used as an alternative, but they might not be reliable due to the differences between teachers (Danielson & McGreal, 2000). This has created the need to create alternative methods for measuring educational outcomes that can inform quality teaching and learning (Pianta & Hamre, 2009).

Measures of instructional quality are a feasible alternative to test-based accountability since such measures capture what teachers are doing to facilitate learning (Boston, 2012). Educational policy in recent decades has led to the establishment of teacher evaluation systems with the intent to measure and improve teacher quality (Danielson, 2007; Garrett & Steinberg, 2015; Lash et al., 2016; Lynch et al., 2017; Pianta & Hamre, 2009). Teacher evaluations are seen as a construct validity measure on student learning and have been shown to be related to student achievement (Milanowski, 2004).

Teacher evaluation systems have evolved over the decades. For example, in the 1940s and 1950s, teachers were evaluated according to their personal traits such as voice, appearance, emotional stability, and warmth (Danielson & McGreal, 2000; White, 2017). In the 1960s, teachers were evaluated on their enthusiasm (White, 2017). However, in the 1970s, the focus of teacher quality shifted to skills in pedagogy – especially in math and science (Danielson & McGreal, 2000; White, 2017). In the 1980s, the work of Madeline Hunter led to a behavioristic view of teaching that emphasized teacher-centered classrooms (Danielson, 2007; Danielson & McGreal, 2000). However, the 1980s and 1990s saw a shift towards more complex student outcomes such as critical thinking, problem solving, and collaborative learning. This resulted in a movement towards teacher evaluation systems based on constructivist instructional strategies (Danielson, 2007; Danielson & McGreal, 2000).

The literature suggests using multiple measures for teacher evaluations such as classroom observations, artifacts, surveys, professional development, and value-added measures (Bill and Melinda Gates Foundation, 2013; Danielson & McGreal, 2000; Garrett & Steinberg, 2015; Lash et al., 2016; Reddy et al., 2019). Effective teacher evaluation systems can also include teacher self-assessments, structured reflection, planning documents, stakeholder feedback, and parent communication (Danielson & McGreal, 2000). The Measures of Effective Teaching (MET) is a seminal study that investigated how to measure teacher quality with reliability and validity (Bill and Melinda Gates Foundation, 2013). The study took place over three years and involved 3,000 volunteer teachers in seven school districts across the United States. During the 2009-10 year, researchers calculated teacher effectiveness using classroom observation results, student perception measures, and student achievement gains. The achievement gains were controlled for prior performance and demographics. During the following year, students were randomly assigned to the participating teachers. The researchers used student achievement data to see if students assigned to high performing teachers learned more than those assigned to less effective teachers. The actual impacts were consistent with predicted impacts. As a result, the researchers concluded that measures of teacher quality can be used as predictors of student growth (Bill and Melinda Gates Foundation, 2013).

A second objective of the MET study was to investigate how much weight should be placed on each measure (e.g., observations, surveys, achievement data) to predict teachers' success most accurately. The study considered four models. The model that weighted student achievement gains at least 65% was the best predictor of teacher success. However, some argued that so much weight on standardized tests might force teachers to put too much emphasis on test performance. In addition, the study found this method to be less reliable than placing less weight on test scores. The data suggests that placing between 33% and 50% weight on prior achievement data is still valid, more reliable, and avoids the possible problem with assigning such a heavy weight to one measure (Bill and Melinda Gates Foundation, 2013).

Subsequent studies on the relationship between teacher scores on evaluation measures and student achievement have been varied, with the majority showing weak to moderate relationships (Lynch et al., 2017). For example, a study in Indonesia investigated the relationship between teacher performance measures and student achievement as measured on national exams (Sirait, 2016). This study used a linear model that controlled for enrollment, teacher experience, and educational background. The results showed a significant relationship between teacher evaluation scores and student achievement across all subjects at the senior high school level. However, there was no significant relationship between teacher evaluation and student achievement at the junior high level (Sirait, 2016). That same year, a study conducted with 713 elementary, middle, and high school teachers from the Unites States found a statistically significant positive correlation between teacher evaluation ratings and student growth on state assessments (Lash et al., 2016). One possible reason for the lack of a strong relationship is the misalignment of teacher evaluation items and measures on standardized tests (Lynch et al., 2017). For example, a teacher may score high on an observation instrument that measures rigorous content and cognitively demanding tasks, whereas students may be asked to perform relatively low-level tasks on a standardized assessment (Lynch et al., 2017). Some studies have found a higher correlation between teacher evaluation scores and student achievement scores when higher cognitive assessments are used (Lynch et al., 2017).

Classroom Observation Instruments

Classroom observations have been shown to be a stable predictor of instructional quality over time and can provide feedback to improve teaching (Boston, 2012; Danielson, 2007; Pianta & Hamre, 2009). The Danielson Framework for Teaching (FFT) is one of the most widely used classroom observation tools in the Unites States (Garrett & Steinberg, 2015). The Danielson Group created the FFT based on research-based strategies that have been shown to create higher levels of student achievement (Danielson, 2007, Milanowski, 2004). The FFT is based on empirical research surrounding a constructivist approach to learning that assumes the most effective learning occurs when students are cognitively engaged with the content (Danielson, 2007; Kettler & Reddy, 2019). The framework organizes teaching practices into four domains:

planning and preparation, classroom environment, instruction, and professionalism (Danielson, 2007). Each domain is further divided into five to six components for a total of 22 components (Danielson, 2007; Danielson & McGreal, 2000; Kettler & Reddy, 2019; Pianta & Hamre, 2009). The FFT is designed to evaluate effective teaching regardless of the subject matter or teaching method (Danielson, 2007).

The research has found moderate positive correlations between FFT scores and student achievement (Bill and Melinda Gates Foundation, 2013; Garrett & Steinberg, 2015). For example, the MET study found moderate correlations between student achievement and teacher FFT scores, which implies that classroom observation scores can be used as predictors of student growth (Bill and Melinda Gates Foundation, 2013).

A subsequent study investigated the validity of the Danielson FFT ratings of teachers as scored by their administrators (Lash et al., 2016). The study used the scores of middle and high school teachers on all 22 components as provided by their principals to measure the internal consistency of the instrument. The study found that principals were consistent in their ratings within each domain. However, the internal consistency was even higher when the average of all components was used. This implies that the domains may not be measuring a unique aspect of teaching and that a composite teacher score could be used (Lash et al., 2016). This study also used a Pearson correlation test to investigate the relationship between teacher ratings and student growth on state assessments. The study found a statistically significant positive correlation between all four domains and student growth in math. This implies that the domain ratings individually and in total can predict student growth scores (Lash et al., 2016).

More recently, Kettler and Reddy (2019) outlined a study that investigated the reliability and validity of the FFT using alternative scoring approaches. The study compared the results of using a composite score for each domain, a composite score for domains two and three, and a total composite score. The validity of the scoring methods was tested by comparing FFT scores to student achievement. The results indicated that none of the scoring methods were good predictors of student achievement after only one observation (Kettler & Reddy, 2019). However, the results showed that the composite scores averaged over three rounds were strong predictors of student growth in achievement. The study found that all six FFT scores used in the study were internally consistent enough to be used for high-stakes decisions when averaged over three observations (Kettler & Reddy, 2019). However, the composite scores were found to be more stable than the traditional scores suggesting they might be a preferable way to use the FFT (Kettler & Reddy, 2019). The MET study confirms this finding as it found that having one full class period observation combined with several shorter observations increased the predictive power of the observation data (Bill and Melinda Gates Foundation, 2013).

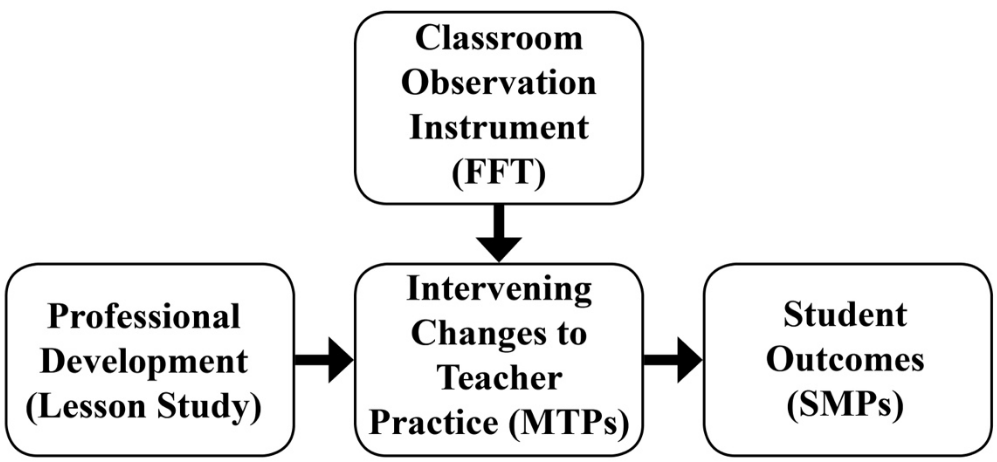
The FFT instrument has also been studied in conjunction with other instruments such as the Classroom Strategies Assessment System (CSAS). The CSAS is designed to measure the frequency of research-based constructivist and direct instruction teaching strategies in the classroom. It has been shown to be predictive of student achievement in ELA and math (Reddy et al., 2019). A recent study conducted by Reddy et al. (2019) investigated the incremental validity of combining the scores of both the CSAS and FFT instruments in predicting student growth scores in ELA and math on standardized tests. When the CSAS scores were used first, the FFT significantly added validity to the scores in ELA but not in math (Reddy et al., 2019). When the FFT scores were used first, the CSAS scores significantly added validity to the scores in math but not in ELA (Reddy et al., 2019). The researchers hypothesized that the FFT instrument may add validity to ELA scores since it is based on a constructivist approach to teaching; whereas, the CSAS might add validity in math because it includes measures for direct instruction (Reddy et al., 2019).

Theoretical Framework: Constructivism

A constructivist theory of learning formed the theoretical framework for this study. A theoretical framework describes how the key elements of a study relate to one another (Ravitch & Riggan, 2016). The purpose of this study was to investigate the impact of lesson study on the professional growth of math teachers as defined by the Danielson FFT. Constructivism is the link that connects lesson study, intended teacher outcomes (MTPs), the Danielson FFT, and intended student outcomes (SMPs; see Figure 1).

Figure 1

Theoretical Framework



Constructivism is a theory of learning which maintains that people construct knowledge through the process of the interaction between what they already know and the new content they experience (Caprioara & Anghelide, 2016; Ultanir, 2012). From an epistemological perspective, the constructivist paradigm assumes that knowledge cannot be given to another person – rather, knowledge must be intellectually constructed (Caprioara & Anghelide, 2016). This implies that interactions and context are necessary for learning to occur (Matthews, 2003). From the didactic point of view, knowledge must be built by the student (Caprioara & Anghelide, 2016). This implies that teachers serve as facilitators for students to construct their own knowledge (Hattie et al., 2017; Matthews, 2003; Powell & Kalina, 2009; Ultanir, 2012). In constructivist classrooms, the teacher activates previous knowledge and provides students opportunities to move from knowledge and comprehension to evaluation and synthesis. In other words, teachers help students fill in knowledge gaps through exploration and inquiry (Lutz & Huitt, 2004).

Theorists

Educational philosophy in the United States has seen an evolution of and fluctuation in educational theories. At the beginning of the 20th century, education in the United States could be described as based on faculty psychology. This philosophy held that the mind consisted of modules or faculties and that learning of one faculty could transfer to the other (Steffe, 2017). In 1901, Edward Thorndike conducted a classic experiment which proved that training of one faculty did not transfer to another (Steffe, 2017). This debunked faculty psychology and gave rise to a behaviorist theory of learning. The behaviorists believed education should be founded on skills and habits through drill and practice (Steffe, 2017). In this traditional model of education, the role of the teacher was to communicate knowledge and to enforce rules of conduct (Dewey, 1938; Ultanir, 2012). Teaching was thought of as communicating a static body of knowledge to the learner. This assumed a passive role on the part of the learner (Dewey, 1938).

Around 1919, John Dewey began a progressive educational movement that resulted from a dissatisfaction with behaviorist approaches (Bates, 2019; Matthews, 2003). John Dewey was an American philosopher and psychologist who promoted the idea that humans construct their own knowledge by interacting with their environment (Lutz & Huitt, 2004). In contrast to learning from texts and teachers, progressive education assumed learning is achieved through individual and social experience (Bates, 2019; Dewey, 1938; Ultanir, 2012). Dewey believed that teachers should not force a curriculum, but rather act as a facilitator for students (Lutz & Huitt, 2004; Matthews, 2003; Steffe, 2017). Dewey also believed that the role of schooling was to prepare students to function in a democratic society (Lutz & Huitt, 2004).

Jean Piaget, a Swiss biologist, philosopher, and behavioral scientist, made valuable contributions to constructivist theory (Lutz & Huitt, 2004; Ultanir, 2012). Like Dewey, Piaget believed that humans cannot just be given knowledge – he viewed learning as the process of mental adaptation as people find themselves in a new situation and must find a solution that is not immediately given (Piaget, 1953). According to Piaget, when humans interact with the environment, they construct cognitive structures through the process of assimilation and accommodation (Lutz & Huitt, 2004; Powell & Kalina, 2009; Ultanir, 2012). Assimilation occurs when new information is added to existing structures – this occurs when a person searches existing schemas to find a known procedure to solve the problem at hand (Piaget, 1953). Accommodation occurs when the initial method does not solve the problem. In this case, the person must change their original schema, which results in the discovery of a new schema (Piaget, 1953). In other words, accommodation is the process of changing mental schemas to accommodate new information resulting from new experiences (Hattie et al., 2017; Lutz & Huitt, 2004; Powell & Kalina, 2009; Ultanir, 2012).

Piaget believed that children construct knowledge according to their perceptions, which can be defined by developmental stages (Bates, 2019; Caprioara & Anghelide, 2016; Powell & Kalina, 2009; Ultanir, 2012). Piaget's developmental stages are the sensorimotor stage, the pre-operational stage, the concrete operational stage, and the formal operational stage (Lutz & Huitt, 2004; Piaget, 1953). During the sensorimotor stage (0-2), children learn through their senses, physical activity, and language. This is followed by the pre-operational stage (2-7) where children develop their own language skills but do not understand the thoughts of others. The next stage is the concrete operational stage (7-11) where children learn to use their own logical reasoning. The final stage is the formal operational stage (11and older) where individuals use higher level thinking and abstract ideas to form knowledge (Piaget, 1953; Powell & Kalina, 2009). The theory of developmental stages has implications for what types of learning experiences are appropriate at each stage of a child's education.

Lev Vygotsky, a Russian philosopher, was also very influential in shaping constructivist thought (Bates, 2019). Like Piaget, Vygotsky believed that children develop cognitively in stages. However, whereas Piaget focused on the child's independent exploration of the world, Vygotsky focused more on the role of social interactions in learning (Aubrey & Riley, 2016; Hattie et al., 2017; Powell & Kalina, 2009). Vygotsky's ideas form the basis for what has come to be known as social constructivism (Aubrey & Riley, 2016; Powell & Kalina, 2009). According to this theory, humans construct knowledge through social interaction, culture, and inner speech (Bates, 2019; Lutz & Huitt, 2004; Powell & Kalina, 2009). Specifically, it is through language that experiences are internalized by the learner and mental structures are formed (Lutz & Huitt, 2004; Powell & Kalina, 2009). According to social constructivism, teachers should promote dialogue in the classroom so students can construct personal meaning of the material (Powell & Kalina, 2009).

Vygotsky is also known for his theory of the zone of proximal development (ZPD). This theory assumes that students learn by acting first on what they can do on their own, then going beyond that with the help of others (Aubrey & Riley, 2016; Bates, 2019). This is also referred to as scaffolding, or the idea that people learn through the support of others (Powell & Kalina, 2009). According to this theory, the role of the teacher is to provide learning experiences to the students just beyond their competence level and offer support as needed (Aubrey & Riley, 2016; Lutz & Huitt, 2004).

Implications for Math Instruction

Constructivism in the classroom derived from the work of John Dewey, Jean Piaget, and Lev Vygotsky (Matthews, 2003). Dewey stressed the idea that learning does not occur in isolation and that teachers must connect content to student experiences (Dewey, 1938; Ultanir, 2012). This requires teachers to be aware of the capacities and past experiences of their students in order to plan quality educational experiences. In addition, teachers must provide time for reflection after active engagement so students can organize and construct new knowledge (Dewey, 1938). Piaget stressed the importance of discovery learning through active experimentation. According to Piaget, teachers must provide students the opportunity to apply familiar means to new situations and discover new means through active experimentation (Piaget, 1953). Vygotsky stressed the importance of social interaction in learning. This implies teachers should promote dialogue in the classroom so students can construct new knowledge (Hattie et al., 2017; Powell & Kalina, 2009).

Although the theories of Dewey, Piaget, and Vygotsky differ, they are all based on the idea that knowledge is constructed by the learner (Lutz & Huitt, 2004). Therefore, constructivist math instruction will contain opportunities for students to be actively involved in solving problems that are situated in real-world contexts (Caprioara & Anghelide, 2016; Hattie et al., 2017; Ultanir, 2012). In constructivist classrooms, teachers are facilitators who encourage students to form their own ideas and conclusions (Ultanir, 2012). In addition, constructivist math teachers situate the learning in the broader curriculum so students can connect new knowledge to their existing cognitive structures (Caprioara & Anghelide, 2016; Hattie et al., 2017). According to social constructivism, math knowledge is constructed through social interaction and collaboration (Caprioara & Anghelide, 2016). This underscores the need for math teachers to provide opportunities for students to engage in mathematical discourse (Hattie et al., 2017; Powell & Kalina, 2009; Schoenfeld, 2020).

The intended student outcomes for math are founded on a constructivist view of learning (Steffe, 2017). The CCSSM contain eight Standards of Mathematical Practice (SMPs) that describe how students are to engage with mathematical content. The SMPs state that students will be able to:

- make sense of problems and persevere in solving them,
- reason abstractly and quantitatively,
- construct viable arguments and critique the reasoning of others,
- model with mathematics,
- use appropriate tools strategically,
- attend to precision,
- look for and make use of structure, and
- look for and express regularity in repeated reasoning (NGA & CCSSO, 2010).

These standards show that students are expected to construct mathematical knowledge through active engagement with the content and through the use of language. This underscores the importance of math teachers understanding of constructivist teaching strategies so they can facilitate these learning experiences (Caprioara & Anghelide, 2016).

The NCTM outlined eight Mathematics Teaching Practices (MTPs) that define high-quality math instruction (NCTM, 2014). These research-based instructional strategies support student achievement of the CCSSM. According to the NCTM, high-quality math teachers:

- establish mathematics goals to focus learning,
- implement tasks that promote reasoning and problem solving,
- use and connect mathematical representations,
- facilitate meaningful mathematical discourse,
- pose purposeful questions,
- build procedural fluency from conceptual understanding,
- support productive struggle, and
- elicit and use evidence of student thinking (NCTM, 2014).

Constructivist teaching strategies are evidenced in the MTPs. Specifically, Dewey's suggestion that students need to be engaged in meaningful experiences can be seen in the importance of tasks and problem solving (Ultanir, 2012). Piaget's idea that students must make connections to form new mental models can be seen in the requirements to problem solve, develop conceptual understanding, and make mathematical representations (Ultanir, 2012). Likewise, Vygotsky's focus on the importance of language can be seen in the requirement for mathematical discourse, and his notion of the ZPD is evidenced in the concept of productive struggle (Lutz & Huitt, 2004; Schoenfeld, 2020).

Implications for Measuring Instruction

Lesson study is theorized to support math teachers in their professional development to provide high-quality instruction (Lewis et al., 2006, 2019; Lewis & Perry, 2017; Takahashi & McDougal, 2016). The NCTM has defined high-quality math instruction by the MTPs that are grounded in constructivist theories (NCTM, 2014). Therefore, a classroom observation instrument grounded in constructivist theory should be aligned to measure the desired teacher outcomes.

The Danielson FFT is the classroom observation instrument currently used in Idaho for teacher evaluations (Rules Governing Uniformity, 2014). The FFT is based on a constructivist approach to teaching that assumes students learn best when they are cognitively engaged with the content (Danielson, 2007; Kettler & Reddy, 2019). The FFT is organized into four domains: planning and preparation, classroom environment, instruction, and professionalism (Danielson, 2007; Danielson & McGreal, 2000; Kettler & Reddy, 2019; Pianta & Hamre, 2009). Many of the MTPs are evidenced in the framework. For example, MTP1 indicates that high-quality math teachers establish goals to focus learning (Hattie et al., 2017; NCTM, 2014). This is present in FFT domain one, which provides a rubric for setting instructional outcomes (Danielson, 2007). Likewise, MTP4 and MTP5 stress the importance of questioning and classroom discourse (Hattie et al., 2017; NCTM, 2014). Rubrics for these indicators are contained in domain three of the framework, which outlines criteria for using question and discussion techniques (Danielson, 2007). In addition to making student thinking visible through classroom discourse, math teachers are tasked with making sure classroom discourse it respectful and inviting (Schoenfeld, 2020). A rubric for creating this culture of learning is contained in domain two of the FFT (Danielson, 2007). As another example, MTP7 indicates that high-quality math teachers support productive struggle (Hattie et al., 2017; NCTM, 2014). This is supported by domain two of the framework that outlines characteristics of a culture for learning where students consistently expend effort to learn (Danielson, 2007). In sum, the theories of constructivism link the intended teacher outcomes from lesson study to the classroom observation instrument used in Idaho for teacher evaluations.

Conclusion

International studies have revealed that K-12 math students in the United States have historically performed below their counterparts in other developed countries (Kolb, 2015; NCTM, 2014; Schmidt, 2012; Stigler & Hiebert, 2009). Since the 1950s, reform efforts have sought to improve the content, focus, and rigor of math education in the United States (Anderson-Pence, 2015; Heise, 2017; Herrera & Owens, 2001; Kolb, 2015; National Commission on Excellence in Education, 1983; Schoenfeld, 2004). Currently, the CCSSM outline what math students in the United States need to know to be successful in college and the work force (NGA & CCSSO, 2010). The literature defines high-quality math instruction as that which provides students the opportunity to engage in complex thinking, persist in problem solving, and participate in mathematical discourse (Hattie et al., 2017; NCTM, 2014; NGA & CCSSO, 2010; Schoenfeld, 2020; Stigler & Hiebert, 2009). The CCSSM are grounded in constructivist learning theory. This requires math teachers to shift from their traditional roles as transmitters of knowledge to facilitators of student-centered classrooms (Blank et al., 2007; Hattie et al., 2017; Herrera & Owens, 2001; Jentsch & Schlesinger, 2017; NCTM, 2014; Schoenfeld, 2004; Takahashi & McDougal; 2016). Highly effective professional development programs can support teachers in executing these reform efforts by developing their knowledge of content and pedagogy (Alamri et al., 2018; Blank et al., 2007; Kruse et al., 2017; Sandholtz et al., 2016; Sztajn et al., 2012). The literature identifies research-based practices for highly effective professional development as being content focused, sustained, job-embedded, collaborative, based on active learning, and include expert support (Aykaç & Yildirim, 2017; Blank et al., 2007, 2010; Danielson & McGreal, 2000; Darling-Hammond et al., 2017; Hammer, 2013; McDonald, 2012; McElearney et al., 2019; Yoon et al., 2007).

Lesson study is a model of professional development that originated in Japan and has become a method of professional development used world-wide in recent decades (Dudley et al., 2019; Godfrey et al., 2018; Lewis et al., 2006, 2019; Seleznyov, 2018; Thinwiangthong et al., 2020; Xu & Pedder, 2015). Lesson study is a model of high-quality professional development where teachers work collaboratively under the direction of a facilitator to research a topic, design and teach a lesson, and reflect on student learning (Druken, 2015; Lewis et al., 2006, 2019; Lomibao, 2016; Moghaddam et al., 2015; Takahashi & McDougal, 2016; Xu & Pedder, 2015). Lesson study is seen as a method of transformational improvement capable of creating cultural and systemic change by creating a shared language about teaching and learning within the profession (Cajkler, 2015 et al.; Dudley et al., 2019; Stigler & Hiebert, 2009; Xu & Pedder, 2015). This process allows teachers to develop professional knowledge collaboratively, to improve the culture of teaching, and to integrate new mandates, ideas, and curriculum (Anderson-Pence, 2015; Druken, 2015; Lewis et al., 2006; Özdemir, 2019; Xu & Pedder, 2015).

The impact of lesson study has been the subject of much research since its worldwide implementation (Cajkler et al., 2015; Dudley et al., 2019; Godfrey, 2018 et al.; Lewis et al., 2006, 2019; Lewis & Perry, 2017; Lomibao, 2016; Moghaddam et al., 2015; Murphy et al., 2017; Schipper et al., 2018; Xu & Pedder, 2015). However, most of the research contains teacher self-reported data, and effective methods to measure the impact of lesson study are still being sought (Dudley et al., 2019). The literature does not contain research measuring the effects of lesson study using state-adopted teacher observation instruments. This study aimed to investigate the impact of lesson study on Idaho math teachers' professional growth using the Danielson FFT. The Danielson FFT has been adopted by Idaho as the classroom observation instrument for the teacher evaluation process (Rules Governing Uniformity, 2014). The FFT is designed to measure research-based instructional strategies based on constructivist learning (Danielson, 2007; Kettler & Reddy, 2019). This is aligned to the characteristics of high-quality math instruction outlined by the NCTM that are also grounded in constructivist theories of learning (Hattie et al., 2017; NCTM, 2014). Therefore, this study aimed to provide additional insight to stakeholders by providing a theoretical basis for the effectiveness of lesson study as a professional development program using the Danielson FFT.

Chapter III

Design and Methodology

Introduction

Students today must develop proficient math skills to be competitive in a global economy (Danielson, 2007; Schmidt, 2012; Stigler & Hiebert, 2009). However, assessments indicate that students in the United States perform lower on math achievement measures than their counterparts in other countries (Guglielmi & Brekke, 2017; National Center for Education Statistics, n.d.; Kolb, 2015; NCTM, 2014; Schmidt, 2012; Stigler & Hiebert, 2009). In 2010, the Common Core State Standards for Math (CCSSM) were implemented to ensure all US students meet specific benchmarks of performance in math (NGA & CCSSO, 2010). This required a fundamental change in how math was taught in the United States – the new standards placed a greater focus on the processes of solving math problems, student thinking strategies, and mathematical discourse (Anderson-Pence, 2015; Jentsch & Schlesinger, 2017; NCTM, 2014). The new standards created the need to provide professional development to math teachers to support them in the implementation of the standards (Kruse et al., 2017; Pehlivan & Güzel, 2020; Schmidt, 2012; Sztajn et al., 2012).

Traditionally, teacher professional development has been provided through one-time events such as workshops, seminars, and conferences (McDonald, 2012). However, the research shows that professional development is more effective when it is sustained, job-embedded, and includes ongoing support (Aykaç & Yildirim, 2017; Blank et al., 2007, 2010; Danielson & McGreal, 2000; Darling-Hammond et al., 2017; Hammer, 2013; McDonald, 2012; McElearney et al., 2019; Yoon et al., 2007). Lesson study is one model of professional development that fits these criteria (Kolb, 2015; Schipper et al., 2018; Thinwiangthong et al., 2020). Lesson study originated in Japan and was first practiced in the United States in the 1990s (Özdemir, 2019; Takahashi & McDougal, 2016; Wright, 2009). Since that time, it has become a popular method of professional development among math teachers and has been shown to improve teacher practice (Dudley et al., 2019; Fernandez, 2002; Lewis et al., 2019; Stigler & Hiebert, 2009; Takahashi & McDougal, 2016; Thinwiangthong et al., 2020; Xu & Pedder, 2015).

During lesson study, teachers work in teams to study, plan, teach, and reflect on a research lesson (Druken, 2015; Lewis et al., 2019; Moghaddam et al., 2015; Takahashi & McDougal, 2016). The process is collaborative and provides opportunities for teachers to be active learners in the context of their day-to-day teaching assignments (Thinwiangthong et al., 2020). The goal of a lesson study team is to gain greater insight into the student learning process (Celik & Guzel, 2020; Pehlivan & Güzel, 2020). This is accomplished as teachers collaboratively plan a lesson and make hypotheses regarding student outcomes (Lewis et al., 2019; Takahashi & McDougal, 2016). One of the team members teaches the lesson while the other members observe and collect data on student learning. Following the live lesson, the team reconvenes to discuss the results. The lesson study process is facilitated by an expert referred to as the knowledgeable other (KO) who provides ongoing expert support to the lesson study team (Lewis et al., 2019; Lomibao, 2016; Takahashi & McDougal, 2016).

There is much research supporting lesson study as an effective model of professional development. The literature indicates lesson study can positively affect teacher content and pedagogical knowledge, attitudes, beliefs towards learning, and teacher self-efficacy (Celik & Guzel, 2020; Druken, 2015; Lewis et al., 2019; Lomibao, 2016; Moghaddam et al., 2015; Özdemir, 2019; Pehlivan & Güzel, 2020; Schipper et al., 2018; Thinwiangthong et al., 2020; White, 2017). However, many of the studies show teacher outcomes using self-reporting instruments such as teacher surveys (Druken, 2015; Lomibao, 2016; Schipper et al., 2018; White, 2017). It is essential to add other methods to the research to triangulate the self-reported data (Boston, 2012). Recent research on the impact of lesson study has included direct observation of the teaching behaviors of lesson study participants (Celik & Guzel, 2020; Pehlivan & Güzel, 2020; Thinwiangthong et al., 2020). In these recent studies, classroom observation instruments were used as a method to measure the changes in teacher practice following participation in lesson study (Pehlivan & Güzel, 2020; Thinwiangthong et al., 2020). This demonstrates the validity of using teacher instructional practice as an outcome of professional development programs. This is also validated by the fact that teacher practice has the greatest influence on student learning (Alamri et al., 2018; Goldhaber, 2016).

Research Design

The purpose of this study was to investigate the impact of lesson study on the professional growth of math teachers in Idaho using the Danielson Framework for Teaching (FFT). The state of Idaho adopted the Danielson FFT to assess high-quality teaching, and districts within the state are encouraged to use the framework for annual teacher evaluations (Idaho Administrative Procedure Act, 2020). A better understanding of the impact of lesson study on the professional growth of math teachers using the Danielson FFT can inform state education agencies regarding the impact of this program. The following research questions offered guidance and focus for this study:

1. What is the impact of lesson study on math teachers' professional growth using the Danielson Framework for Teaching (FFT) classroom observation instrument?
2. What are math teachers' perceptions of the impact that lesson study has on their ability to engage students in learning as described by the Danielson FFT?

3. What are administrators' perceptions of the impact that lesson study has on their math teachers' professional growth as defined by the Danielson FFT classroom observation instrument?

This study followed a convergent mixed methods design. Data from the Danielson classroom observation instrument, teacher focus group interviews, and administrator interviews were triangulated to gain insight into the impact of lesson study from multiple perspectives. Triangulating data reduces the potential bias inherent in each method and increases the validity of the findings (Maxwell, 2013). In this way the researcher drew on the strengths of quantitative and qualitative methods (Creswell & Guetterman, 2019; Marshall & Rossman, 2016).

The researcher used the Danielson FFT classroom observation instrument to collect quantitative data for the study. The researcher looked for trends in the classroom observation scores for teachers with 0-6 years of experience with lesson study. The researcher also compared classroom observation scores between two groups of participants – teachers who had participated in lesson study for 0-2 years and those who had participated 3-6 years. Qualitative descriptive methods guided the qualitative portion of the study. Qualitative description can provide useful data in mixed methods studies (Neergaard et al., 2009). The purpose of qualitative description is to provide a focused summary of a narrow topic in the everyday language of those events (Neergaard et al., 2009; Sandelowski, 2000; Willis et al., 2016). Qualitative description also seeks factual descriptions of phenomena from the perspectives of the participants (Colorafi & Evans, 2016; Sandelowski, 2000). The researcher used qualitative descriptive methods to gain insight on the impact of lesson study from the perspective of the participants in their own language. Teacher professional learning is complex and understanding the participants' experiences with lesson study helped the researcher understand its impact on their professional growth (King, 2013).

Qualitative description relies heavily on semi-structured interviews (Neergaard et al., 2009). Focus group interviews are an efficient way to obtain a broad perspective on a narrow topic in qualitative descriptive research (Neergaard et al., 2009). The researcher gained insight into teachers' experiences with lesson study through semi-structured focus group interviews. The purpose of the focus group interviews was to gain a collective perspective of how participation in lesson study had impacted their teaching practice with a focus on their students' engagement in learning. According to the Danielson FFT, students in high-quality classrooms expend effort to learn, engage in high-level activities, serve as a resource to classmates, engage in classroom discourse, and monitor their own progress toward the learning target (Danielson, 2007). Finally, the researcher conducted semi-structured interviews with administrators of schools that participate in lesson study programs. The purpose of these interviews was to determine administrator perceptions of how math teachers' participation in lesson study had impacted their teachers' professional growth as defined by the Danielson FFT.

Consistent with convergent mixed methods, the researcher collected quantitative data and the qualitative data simultaneously. Qualitative and quantitative methods can complement each other and offer means for analyzing a topic from different perspectives. The quantitative data was used to answer the "how much" question and the qualitative data was used to answer the "what", "why", and "how" questions (Neergaard et al., 2009; Sandelowski, 2000). The researcher compared the quantitative and qualitative findings to see if the two methods had similar or dissimilar results (Creswell & Guetterman, 2019). This mixed methods approach provided insight into the empirical information regarding the teacher outcomes of lesson study, as well as a deeper understanding regarding the complex process of teacher professional growth

(Creswell & Guetterman, 2019).

Participants

The participants for this study included K-12 math teachers and administrators from two rural school districts in north-central Idaho. Appendix A contains the site permission letters from the districts. Table 1 contains demographic information for the participating school districts.

Table 1

School District Demographics

Characteristic	District 1	District 2
Race		
White	94.1%	96.4%
Black or African American	0.4%	0.2%
American Indian or Alaska Native	3.1%	0.5%
Asian	0.8%	0.1%
Hispanic or Latino	2.6%	1.9%
More Than One Race	1.3%	2.1%
Income		
Income per Capita	$20,373	$19,434
Income per Household	$42,079	$36,208
Income Below Poverty Line	10%	16.3%

School district 1 began practicing lesson study during the 2016-17 school year. The program grew and became a school-wide program within the district during the 2018-19 school year. School district 2 started practicing lesson study with seven teachers during the 2016-17 school year and expanded to school-wide practice during the 2020-2021 school year. Both districts are located Idaho’s Region II. Their lesson study programs are facilitated by the regional math center housed at Lewis & Clark State College. The program includes a required two-day summer workshop where they study the Mathematics Teaching Practices (MTPs) outlined in *Principles to Actions* (NCTM, 2014). This provides a common language for them to discuss research themes during the upcoming school year. Every teacher engages in two lesson study cycles every year, with every cycle consisting of two full days. On the first day, the teachers study the research theme, design a research lesson, make hypotheses of student learning, and plan for data collection. The teachers choose the research theme based on the gap between where the students are and the desired student outcomes. The regional math specialist, who serves as the facilitator, provides the teachers with research articles based on the research theme. The teachers then co-plan the research lesson and make three to five hypotheses of student learning based on the research articles. On the second day, one teacher teaches the research lesson. The remaining teachers collect data surrounding the hypotheses of student learning. The post-lesson discussion focuses on what was observed relative to the hypotheses. These districts follow the model of lesson study outlined in Takahashi and McDougal (2016) where the research lesson is not retaught.

The researcher recruited participants through the regional math specialist who served as a gatekeeper to lesson study participants in Region II. The regional math specialist identified six schools that engage in lesson study. Four of the schools reside in district 1 – two elementary and two secondary. The other two schools reside in district 2 – one elementary and one secondary. The researcher sent an email to the principal at each of the six identified schools inviting them to involve their school in the study. The researcher received responses from four schools – three elementary and one secondary. This outcome limited the number of secondary teachers available to recruit for the study. As a result, the study participants consisted of 33 elementary teachers and four secondary teachers.

The researcher used purposeful sampling to recruit K-12 math teachers for the classroom observations. Purposeful sampling is employed to deliberately select participants who have had a unique experience (Alase, 2017; Maxwell, 2013). The researcher recruited participants based on the number of years they had engaged in lesson study. This allowed the researcher to look for trends in classroom observations scores as teachers progress through the lesson study program. The researcher attempted to recruit an even number of teachers who had participated in lesson study for 0-2 years and 3-6 years. The researcher sent an explanatory email with an invitation to participate to the teachers who met the criteria (see Appendix B). However, this resulted in a zero-response rate. The researcher concluded this was the result of a lack of trust between the researcher and the participating districts. Therefore, the researcher conducted the focus group interviews first to establish a personal relationship with the participants. The researcher personally invited the focus group participants to participate in the classroom observation portion of the study. This resulted in a higher response rate, but still short of the desired number of classroom observations needed for the study. The researcher then used the snowball technique – teachers who had consented to have a math lesson video recorded were asked to identify colleagues who might also be willing to have a math lesson video recorded. As a result, the researcher was able to recruit 11 teachers who had participated in lesson study for 0-2 years and eight teachers who had participated in lesson study for 3-6 years. The researcher observed and video-recorded a 30–60-minute math lesson for those teachers who agreed to the classroom observation. Participants completed an informed consent form (see Appendix C) at the time of the classroom visit. Table 2 contains a summary of the participants who consented to a video-recorded classroom observation.

Table 2

*Classroom Observation Participant Summary (*N *= 19)*

Demographic	
Elementary Teachers	15
Secondary Teachers	4
Years Teaching (Average)	16
Years Teaching (Range)	1-33
Years in Lesson Study (Average)	2.8
Years in Lesson Study (Range)	0-6

Qualitative descriptive methods rely on purposeful sampling to identify information-rich cases (Sandelowski, 2000). The researcher used purposeful sampling to recruit teachers for focus group interviews who had participated in at least one cycle of lesson study. All elementary teachers and all secondary math teachers at the six schools identified in Region II were invited to participate via email (see Appendix D). The researcher scheduled focus group interviews with the 27 teachers who responded. The researcher attempted to organize participants into focus groups of equal sizes. However, scheduling conflicts proved to be too difficult to facilitate this. Therefore, the researcher scheduled 1-2 interview times at each school. Teachers were invited to attend any session that fit their schedule. The researcher scheduled separate individual interviews with those teachers who wanted to participate but could not attend the focus group interview times. The researcher used the same interview protocol for all interviews regardless of the number of participants at each session (see Appendix E). The participants signed an informed consent form at the time of the interview (see Appendix F). Table 3 provides a summary of the demographics of each focus group.

Table 3

*Focus Group Participant Summary (*N *= 27)*

Demographic	Focus Group					
	1	2	3	4	5	6
Elementary Participants	8	2	5	0	6	4
Secondary Participants	1	0	0	1	0	0
Total Participants	9	2	5	1	6	4
Teaching Years (Average)	11.7	11.5	9.2	15	15	7
Teaching Years (Range)	2-25	11-12	1-26	15	3-30	2-10
Years in Lesson Study (Average)	3.7	3.5	2.8	5	2	2.3
Years in Lesson Study (Range)	1-6	2-5	1-5	5	1-3	2-3

The researcher used purposeful sampling to recruit administrators for qualitative interviews. All principals at the six identified schools in Region II were invited to participate via email (see Appendix G). The researcher conducted a semi-structured one-on-one interview with the four administrators who agreed to participate. Participants signed an informed consent form at the time of the interview (see Appendix H). Table 4 contains the demographics of the consenting administrators. To avoid possible bias, the researcher did not have a professional relationship with any of the participants prior to the study.

Table 4

*Administrator Interview Participant Summary (*N *= 4)*

Demographic	
Elementary Administrators	3
Secondary Administrators	1
Years Administrating (Average)	6.5
Years Administrating (Range)	3-15
Years School in Lesson Study (Average)	5.3
Years School in Lesson Study (Range)	3-6

Data Collection

The researcher used the Danielson FFT classroom observation instrument to collect quantitative data. Qualitative measures included semi-structured focus group interviews with K-12 math teachers and one-on-one semi-structured interviews with administrators. The researcher offered a $30 Amazon gift card for both the classroom observations and the interviews as incentive for participating. The researcher kept the data confidential by assigning case numbers to the classroom videos and by assigning aliases to the interview participants. The researcher kept the data secure on a password protected computer. The researcher will delete all stored files on the password protected computer within three years of the completion of the study in keeping with the Federal-Wide Assurance Code (45 CRF 46.117).

Quantitative Data Collection

Quantitative data was collected using the Danielson FFT classroom observation instrument. The researcher video recorded a 30–60-minute math lesson for each participant. The researcher recruited an expert Danielson consultant to score each video using the classroom observation instrument (see Appendix I). The video samples were divided into two groups – teachers who had participated in lesson study for 0-2 years and teachers who had participated in lesson study for 3-6 years. The researcher compared the classroom observation scores between the two groups for various components on the Danielson FFT. This data added insight to the first research question: What is the impact of lesson study on math teachers' professional growth using the Danielson Framework for Teaching (FFT) classroom observation instrument?

Qualitative Data Collection

Qualitative methods aim to uncover the participants point of view in the context and setting of the study (Marshall & Rossman, 2016). Qualitative descriptive research relies heavily on semi-structured or open-ended individual or focus groups interviews – this allows the researcher to collect a broad range of information (Sandelowski, 2000). Qualitative measures for this study included teacher focus group interviews and one-on-one administrator interviews.

The researcher conducted semi-structured focus group interviews with teachers who had participated in at least one cycle of lesson study. Focus groups are conducted with different individuals to facilitate the identification of trends in perceptions and opinions of the participants (Marshall & Rossman, 2016). Interview protocols in qualitative descriptive studies are designed to create rich data but can be slightly more structured than in those used in other methods to focus on specific topics (Marshall & Rossman, 2016; Neergaard et al., 2009). In addition, interview questions in qualitative descriptive research may be guided by a conceptual or theoretical framework and may specify the variables or relationships under investigation (Willis et al., 2016). The interview protocol for this study was designed to investigate the variable of student engagement in learning and was guided by the principles of constructivist learning. The questions were designed to focus the participants' attention to student engagement in learning as defined by the Danielson FFT such as student engagement in learning and student discourse (see Appendix E). A face validity check of the focus group interview protocol was performed by an expert panel consisting of two university professors and one secondary administrator (Marshall & Rossman, 2016). The validity check did not require any changes to the focus group interview protocol.

Pilot-testing interview instruments allows researchers to determine if interview questions work as intended (Maxwell, 2013). The researcher piloted this interview protocol with a focus group of three elementary teachers not participating in the study. It is important for researchers to explain what they learned from piloting interview protocols (Marshall & Rossman, 2016). The researcher in this study obtained feedback as to the clarity and length of the questions and made revisions based on this feedback. Specifically, the researcher revised the transition question to focus the participants' attention to the learning culture among their students as there was some confusion between the learning culture of their classrooms and their professional learning culture. The researcher also added an additional key question to distinguish between the teacher's ability to assess learning and the students' ability to self-assess their learning (see Appendix E). The protocol ensured the researcher used the same procedures with each participant. Using the same procedures with each participant increases the reliability of the research (Colorafi & Evans, 2016). In qualitative descriptive research, follow up questions may be asked to enrich and provide depth to the data (Willis et al., 2016). The semi-structured interview design allowed the researcher to stick to the research questions, while being flexible enough to use impromptu probes for elaboration or clarification (Creswell & Guetterman, 2019; Marshall & Rossman, 2016). The interviews were audio recorded so they could be transcribed verbatim by a transcriptionist (Alase, 2017). Effective focus group interviews are conducted in a natural setting (Marshall & Rossman, 2016). Therefore, the researcher allowed the participants to select the location for the interviews so they would be comfortable sharing thoughts and opinions. At the end of the interview, the researcher made a concluding statement that articulated the next steps and explained the opportunity for the participants to check the information. Member checking has been found to increase the validity of thematic outcomes (Maxwell, 2013; Willis et al., 2016). The researcher contacted the focus group participants through email after the initial analysis and invited them to review the researcher's themes and outcomes. The researcher also used interview field notes as a method to reflect on how things might have interfered with the quality of the data and potential interference with interpretation (Marshall & Rossman, 2016). The focus group interview data provided additional understanding related to the second research question: What are math teachers' perceptions of the impact lesson study has on their ability to engage students in learning as described by the Danielson FFT?

Administrators are in a unique position to offer perspectives on the professional growth of their teachers since they perform annual teacher evaluations using the Danielson FFT classroom observation instrument. Four administrators were interviewed to gain insight into the third research question: What are administrators’ perceptions of the impact that lesson study has on their math teachers’ professional growth as defined by the Danielson FFT? The key questions in this interview protocol were designed to be open-ended to allow the participants to voice their perceptions of how lesson study has impacted the professional growth of their math teachers (Creswell & Guetterman, 2019). In qualitative descriptive research, follow up questions may be asked to enrich and provide depth to the data (Willis et al., 2016). The follow-up questions in this protocol were designed to focus the participants’ attention to professional growth as defined by the Danielson FFT (see Appendix J). A face validity check of the administrator interview protocol was performed by an expert panel consisting of two university professors and one secondary administrator (Marshall & Rossman, 2016). The validity check did not require any changes to the administrator interview protocol.

Pilot-testing interview instruments allow researchers to determine if interview questions work as intended (Maxwell, 2013). The researcher piloted this interview protocol with one secondary administrator not participating in the study. It is important for researchers to explain what they learned from piloting interview protocols (Marshall & Rossman, 2016). The researcher in this study obtained feedback as to the clarity and length of the questions and made revisions based on this feedback. As a result of the pilot interview, the researcher changed the order of the key questions. In addition, the researcher added an additional question to distinguish between teachers' and students' explanations of mathematical content (see Appendix J). The protocol ensured the researcher used the same procedures with each participant. Using the same procedures with each participant increases the reliability of the research (Colorafi & Evans, 2016). The interviews were audio recorded so they could be transcribed verbatim by a transcriptionist (Alase, 2017). Member checking has been found to increase the validity of thematic outcomes (Maxwell, 2013). Therefore, the researcher provided a concluding statement after the interview to articulate the next steps and to provide participants the opportunity for participants to check on the results. The researcher contacted the interview participants through email after the initial analysis to invite them to review the researcher's themes and outcomes. The researcher also used interview field notes as a method to reflect on how things might have interfered with the quality of the data and potential interference with interpretation (Marshall & Rossman, 2016).

Analytical Methods

Quantitative Methods

The Danielson FFT Classroom Observation Instrument. The Danielson framework organizes teaching practices into four domains: planning and preparation, classroom environment, instruction, and professionalism (Danielson, 2007). Each domain is further divided into five to six components for a total of 22 components (Danielson, 2007; Danielson & McGreal, 2000; Kettler & Reddy, 2019; Pianta & Hamre, 2009). Table 5 contains a list of the Danielson teaching components from the framework that were analyzed in this study.

Table 5

Danielson Framework Components Analyzed

Domain	Component	Description
2	A	Creating an Environment of Respect and Rapport
2	B	Establishing a Culture for Learning
3	A	Communicating with Students
3	B	Using Question and Discussion Techniques
3	C	Engaging Students in Learning
3	D	Using Assessment in Instruction

The researcher selected these six components because they are observable during live instruction and are aligned to the attributes of high-quality math instruction outlined by the NCTM (NCTM, 2014). Analyzing the trends among lesson study participants on these components provided information regarding the impact of lesson study on teacher professional growth. The following describes how these components from the Danielson FFT are aligned to intended teacher outcomes.

Creating an Environment of Respect and Rapport. Social constructivist theory suggests that social interaction plays a critical role in cognitive development (Hattie et al., 2017; Lutz & Huitt, 2004; Powell & Kalina, 2009). The CCSSM require students to engage in the social aspect of mathematics by engaging in mathematical discourse including critiquing the reasoning of their classmates (NGA & CCSSO, 2010). The discourse should be respectful and inviting so that students feel comfortable taking intellectual risks (Hattie et al., 2017; Schoenfeld, 2020; Thinwiangthong et al., 2020). Component 2A of the framework is designed to measure this aspect of teaching (see Appendix I). The rubric for this component describes a distinguished classroom as one where students contribute to high levels of civility and are comfortable taking intellectual risks (Danielson, 2007).

Establishing a Culture for Learning. Students in high-quality classrooms strive to continuously improve and are trained to persevere in problem solving (NCTM, 2014; Strom et al., 2018). Great mathematicians knew how to struggle, and teachers should help students enjoy the struggle of math (Hattie et al., 2017). Research shows that students who struggle with a problem before being presented clarifying instruction outperform traditionally taught students (Hattie et al., 2017). This is consistent with Vygotsky's theory of the zone of proximal development which implies that students learn by acting first on what they can do on their own, then going beyond that with the help of others (Powell & Kalina, 2009; Schoenfeld, 2020). Teachers can help students enjoy the struggle of math by supporting or scaffolding their work. In turn, students will make sense of problems and persevere in solving them. Component 2B of the framework is designed to measure this aspect of teaching (see Appendix I). The rubric for this component describes the proficient classroom as one where students understand their role as learners and consistently expend effort to learn (Danielson, 2007).

Communicating With Students. Central to high-quality instruction is the establishment of learning goals that are connected to the big mathematical ideas (NCTM, 2014; Schoenfeld, 2020). Effective teachers design clear learning intentions that are specific, concrete, and measurable (Hattie et al., 2017; NCTM, 2014). Teachers must communicate the learning intentions to the students along with the success criteria. In this way, students can evaluate their own progress (Hattie et al., 2017; Thinwiangthong et al., 2020). Learning intentions can include language intentions so that students learn to attend to the precise use of math vocabulary, construct arguments, explain reasoning, and critique the reasoning of classmates (Hattie et al., 2017). High-quality teachers also create learning experiences that develop students' conceptual understanding through explanations and examples. Lessons follow logical progressions from exploration to discussion to reasoning (Jentsch & Schlesinger, 2017; NCTM, 2014; Strom et al., 2018). Effective math teachers also clearly model and communicate mathematical concepts including how representations can be used for problem solving (NCTM, 2014; Schoenfeld, 2020). This provides a means for students to make their thinking visible (Jentsch & Schlesinger, 2017; NCTM, 2014). Component 3A of the framework is designed to measure these aspects of teaching (see Appendix I). The rubric for this component describes the proficient classroom as one where the instructional purpose is clearly communicated to students, strategies are modeled, and teachers and students attend to the precise use of academic vocabulary (Danielson, 2007).

Using Question and Discussion Techniques. A high-quality math classroom is one where student discourse is initiated, students carry the conversation themselves, and students defend and justify their thinking (NCTM, 2014; Strom et al., 2018). Effective teachers facilitate high-quality math instruction with purposeful questions and require students to reflect on their answers and those of their classmates (Hattie et al., 2017; NCTM, 2014). This provides opportunity for students to construct their learning through language as they articulate their thoughts and clarify their arguments (Powell & Kalina, 2009). In addition, when students explain their thinking verbally, students can consider multiple solutions to a problem and compare their solutions to their classmates (Celik & Guzel, 2020; Hattie et al., 2017; Schoenfeld, 2020). Component 3B of the framework is designed to measure these aspects of teaching (see Appendix I). The rubric for this component describes the proficient classroom as one where the questions are used to promote student thinking and students are challenged to justify their thinking (Danielson, 2007). The distinguished classroom is described by students who formulate many questions, initiate topics, and change one another's thinking (Danielson, 2007).

Engaging Student in Learning. The highest level of learning occurs when students construct knowledge for themselves. Students should have the opportunity to construct their understanding in meaningful contexts. The CCSSM show that students are expected to construct mathematical knowledge through active engagement with the content (NGA & CCSSO, 2010). According to the NCTM, math teachers are expected to facilitate tasks that promote reasoning and problem solving (Caprioara & Anghelide, 2016; NCTM, 2014). Teachers can facilitate deep learning with tasks that are open-ended and have multiple strategies or multiple solutions (Schoenfeld, 2020). This complex thinking can be supported in whole group and small group situations (Pehlivan & Güzel, 2020). Effective math teachers provide opportunities for their students to explain and justify their thinking, represent mathematical concepts, and apply math to solve real-world problems (Celik & Guzel, 2020; Hattie et al., 2017). Component 3C of the framework is designed to measure these aspects of teaching (see Appendix I). The rubric for this component describes the distinguished classroom as one where students are intellectually engaged in activities that require complex thinking. In addition, students initiate inquiry and serve as resources for one another (Danielson, 2007).

Using Assessment in Instruction. High-quality teachers use assessment as an ongoing process to inform instruction, adjusting as necessary (NCTM, 2014). Formative assessment supports student learning through high-level, open-ended questioning (Hattie et al., 2017). This provides the evidence of student learning that allows the teacher to provide feedback (Schoenfeld, 2020; Thinwiangthong et al., 2020). In high-quality programs, students learn to assess their learning relative to the success criteria and recognize the quality of their own work (Hattie et al., 2017; NCTM, 2014). Students can even have input to the rubrics for mathematical tasks and projects (Hattie et al., 2017). Component 3D of the framework is designed to measure these aspects of teaching (see Appendix I). The rubric for this component describes the distinguished classroom as one where assessment is fully integrated into instruction, students have contributed to the success criteria, there are a variety of forms of feedback, and student self-assess and monitor their own progress (Danielson, 2007).

Quantitative Data Analysis

Each of the above components was scored using the rubric contained in the Danielson FFT (see Appendix I) on a scale of one to four as follows: (1) Unsatisfactory; (2) Basic; (3) Proficient; (4) Distinguished (Danielson, 2007). The scores were analyzed using Version 27 of IBM's Statistical Package for the Social Sciences (SPSS) software. The researcher generated box plots for the scores of each component to identify outliers in each group (Field, 2013). The researcher then used descriptive statistics to analyze the trends in scores according to the number of years participants engaged in lesson study. The researcher looked at trends in scores for components 2A, 2B, 3A, 3B, 3C, and 3D. The researcher then investigated the impact of lesson study on the professional growth of teachers by dividing the sample into two groups – observations from participants who had participated in lesson study 0-2 years and observations from participants who had participated in lesson study 3-6 years. The researcher used a Mann Whitney U test to compare the scores between the two groups. A Mann Whitney U Test is a non-parametric equivalent to the independent-samples t-test and can be used to compare two groups on the same variable with small samples sizes (Field, 2013; Frey, 2016; Laerd Statistics, 2015). The Mann Whitney U test assumes there is one dependent variable measured at the ordinal or continuous level (Laerd Statistics, 2015). In this study, the dependent variable was the score from the Danielson classroom observation instrument. The Mann Whitney U test assumes there is one independent variable that consists of two independent groups. In this study, the independent variable was the group number. The Mann Whitney U test assumes the two groups consist of completely independent samples (Laerd Statistics, 2015). In this study, the observations were independent with no participant in more than one group.

The Mann-Whitney U tests ranks each score of the dependent variable from smallest to largest across the entire sample. The ranks for each group are averaged resulting in a mean rank for each group. The null hypothesis states there is no statistically significant difference in the mean ranks between the groups (Field, 2013; Laerd Statistics, 2015). In this study the null hypothesis was that there would be no difference in mean rank scores between teachers who had participated in lesson study 0-2 years and those who had participated in lesson study 3-6 years. The researcher tested the hypothesis by analyzing the p value resulting from the Mann Whitney U test. The SPSS 27 software generates two p values for the Mann Whitney U test. The first is the asymptotic p value which is the value p approaches at the sample size increases. The other is the exact p value for the specific sample under investigation. When the dependent variable consists of a small number of ordinal possibilities (e.g., a Likert scale) there can be a large number of ties. The exact p value does not account for ties and therefore may be inflated. In this case it is recommended to use the asymptotic p value (Laerd Statistics, 2015). The researcher in this study used the asymptotic p value since the classroom observation scores ranged from 1-4 creating a likelihood for ties. The researcher considered an asymptotic p value of less than 0.05 as significant (Field, 2013).

The Mann Whitney U test can also be used to determine if there is a statistically significant difference between the median scores between the groups. However, this requires the additional assumption that the shapes of the distributions between both groups be similar. This can be done by visually inspecting the bar chart distributions for each group (Laerd Statistics, 2015). The researcher in this study generated bar chart distributions for Group 1 and Group 2 for each component and visually inspected the graphs to determine similarity of shape. If the shapes were similar, the researcher reported the findings in terms of the median scores. If the shapes were not similar, the researcher reported the findings in terms of the mean rank scores. The researcher presented the results to explain the impact of lesson study on teacher professional development using the Danielson classroom observation instrument (Creswell & Guetterman, 2019; Hoy & Adams, 2016).

Qualitative Analysis Methods

The researcher used qualitative descriptive methods to analyze the qualitative data. Qualitative descriptive data analysis requires the researcher to analyze verbal information to determine substantive summaries. Codes are usually applied, but they are generated from the data themselves. The findings are stated in a way that best represents the data (Willis et al., 2016). In this approach, interview data is coded from verbatim transcripts (Colorafi & Evans, 2016). The researcher in this study used verbatim transcripts and a combination of open and a priori coding to identify substantive categories to describe the participants meanings (Maxwell, 2013).

Focus Group Interviews. The researcher used qualitative descriptive methods to analyze semi-structured focus-group interview data. A transcriptionist transcribed the focus group interview data verbatim. The transcripts were created with large margins for the researcher to apply codes and make remarks (Colorafi & Evans, 2016). It is important in qualitative descriptive research for the researcher to become familiar with the data by reading and rereading the material (Alase, 2017; Marshall & Rossman, 2016; Maxwell, 2013; Saldaña, 2016). The researcher in this study read and reread the transcripts multiple times and kept analytic memos to get a sense of emerging themes (Alase, 2017; Saldaña, 2016). Analytic memos are brief narratives used to document the researchers' reflections and thinking about the data (Colorafi & Evans, 2016; Maxwell, 2013). The researcher used the memos to identify statements that represented the meaning of the participants' experiences (Alase, 2017). The analytic memos also provided an audit trail of all decisions made throughout the analysis (Willis et al., 2016).

The researcher used a priori and open coding to identify meaning units in the data. A priori codes allowed the researcher to organize responses according to components in the Danielson FFT (Saldaña, 2016). Table 6 summarizes the a priori codes. Open coding allows the researcher to develop codes based on what the data shows (Maxwell, 2013). The researcher also used open coding to allow themes regarding lesson study to emerge that might be outside the Danielson framework. The researcher used descriptive codes as a first level coding strategy. Descriptive coding uses nouns to describe passages of qualitative data that link sections of similar content (Saldaña, 2016). Second level coding strategies organize the codes into broader themes (Colorafi & Evans, 2016; Maxwell, 2013). The researcher used process coding as a second cycle coding strategy. Process coding looks for action in the data by identifying words in a gerund form (a verb ending in "ing). The researcher used process codes to look for action in the data to answer the second research question regarding student engagement during math instruction. All the themes were integrated into a central theme (Alase, 2017). The researcher searched for negative evidence of the theme to increase the validity of the study (Colorafi & Evans, 2016; Marshall & Rossman, 2016). The researcher then wrote textual descriptions of the themes, including verbatim statements from the participants. Verbatim statements have been shown to strengthen the reliability and validity of the findings (Patton, 2002). Respondent validation has also been shown to increase the validity of findings (Maxwell, 2013). Therefore, the researcher sent the research themes to the participants via email to ensure that they accurately represented the intent of the participants. Participant responses did not require any changes to the results.

Table 6

A Priori Focus Group Interview Codes

Descriptive Code	Component
Learning Culture	2A, 2B
Student Explanations of Content	3A
Question and Discussion Techniques	3B
Student Engagement	3C
Assessment in Instruction	3D
Student Self-Assessment	3D
Student Outcomes	n/a

Note. The a priori codes correspond to components from the Danielson FFT with an addition of student outcomes.

Administrator Interviews. The researcher used qualitative descriptive methods to analyze semi-structured one-on-one interview data. A transcriptionist transcribed the interview data verbatim. The transcripts were created with large margins for the researcher to apply codes and make remarks (Colorafi & Evans, 2016). It is important in qualitative descriptive research for the researcher to become familiar with the data by reading and rereading the material (Alase, 2017; Marshall & Rossman, 2016; Maxwell, 2013; Saldaña, 2016). The researcher in this study read and reread the transcripts multiple times and kept analytic memos to get a sense of emerging themes (Alase, 2017; Saldaña, 2016). Analytic memos are brief narratives used to document the researchers' reflections and thinking about the data (Colorafi & Evans, 2016; Maxwell, 2013). The researcher used the memos to identify statements that represented the meaning of the participants' experiences (Alase, 2017). The analytic memos also provided an audit trail of all decisions made throughout the analysis (Willis et al., 2016).

The researcher used open coding to identify meaning units in the data (Maxwell, 2013). The researcher used process coding to break the interview data into discrete parts (Saldaña, 2016). Process coding looks for action in the data by identifying words in a gerund form (a verb ending in "ing). These codes can be used to identify actions that change over time (Saldaña, 2016). This method allowed the researcher to look for the process of teacher professional growth resulting from lesson study. Pattern coding can be used as a second level coding (Colorafi & Evans, 2016). The researcher in this study used pattern coding as the second level coding method to identify emerging themes (Saldaña, 2016). The researcher then wrote textual descriptions of the themes, including verbatim statements from the participants. Verbatim statements have been shown to strengthen the reliability and validity of the findings (Patton, 2002). The researcher sent the research themes to the participants via email to ensure that they accurately represented the intent of the participants. Respondent validation has been shown to increase the validity of the findings (Maxwell, 2013). Participant responses did not require any changes to the results. The researcher also searched for negative evidence of the research theme to increase the validity of the study (Colorafi & Evans, 2016; Marshall & Rossman, 2016).

Role of the Researcher

It is essential to understand the role of the researcher to determine potential sources of bias in the findings (Colorafi & Evans, 2016; Creswell & Guetterman, 2019). It is not reasonable to eliminate researcher bias. However, it is important to understand how the researcher's expectations may have influenced the outcome of the study (Maxwell, 2013).

As a former math teacher, the researcher of this study was familiar with math instruction and was sympathetic towards math teachers implementing the CCSSM. As a former science teacher, the researcher was a proponent of constructivist instructional strategies and desired to see them used in mathematical instruction. In addition, the researcher had experience delivering professional development to elementary and secondary teachers in instructional methods. During this previous experience, the researcher found the elementary teachers to be more receptive to instructional change and found secondary teachers to be more resistant to changes in curriculum and instruction. The researcher was motivated to find professional development programs that would be effective for elementary and secondary teachers.

The researcher's professional assignment at the time of the study was that of university supervisor in an education department. In this capacity, the researcher used the Danielson FFT to evaluate the performance of pre-service teachers in Idaho. The researcher was familiar with the Danielson FFT classroom observation instrument, and desirous that teachers would see the connection between professional development programs and the Danielson FFT. In addition, the researcher had a growth mindset and viewed the FFT observation instrument as an opportunity for growth in a professional community. The researcher was under the opinion that teachers should be open and willing to discuss their progress as defined by the Danielson FFT.

The role of the researcher in this study was that of an objective observer. However, prior experiences introduced the possibility of bias from the researcher towards mathematical instruction, professional development, and the Danielson FFT classroom observation instrument. Research suggests that it is important for the researcher to bracket (keep separate) his/her perspective to have an objective view of the perspective of the participants (Alase, 2017; Fuster, 2019; Qutoshi, 2018). Therefore, the researcher kept a bracketing research journal as a method to document her own thoughts and feelings and reflect on her practice as a researcher throughout the study, as this has been found to increase the validity of the results (Qutoshi, 2018; Ravitch & Riggan, 2016. In addition, the researcher used member checking, which has also been found to reduce researcher bias (Maxwell, 2013).

Limitations

The purpose of this study was to examine the effect of lesson study professional development programs on the professional growth of math teachers in Idaho. This study included an examination of classroom observation data using the Danielson FFT, teacher focus group interviews, and one-on-one administrator interviews. Limitations are present in any study. Creswell and Guetterman (2019) state that "limitations are potential weaknesses or problems with the study identified by the researcher" (p. 200). However, by addressing the limitations and weaknesses of the study, the researcher can inform future research on the subject. Sampling choices create limitations on the generalizability of a study (Colorafi & Evans, 2016). The researcher used purposeful sampling to select teacher participants based on the number of years they had participated in lesson study. However, when studying teachers and their practice, you are most likely to develop relationships with exemplary teachers who are eager to discuss their teaching practices. Less proficient teachers may be reluctant about sharing inadequacies (Maxwell, 2013). Therefore, teachers who were willing to volunteer in this study may be high performing teachers. Therefore, the results may not be generalizable to all teachers who engage in lesson study. In addition, qualitative description is an effective way to obtain a description of a phenomenon. However, its' findings may be less generalizable since it is low-inferential in nature (Neergaard et al., 2009).

The demographics of the participating districts also presented a limitation. Namely, the race makeups of the districts were 94.1% and 96.4% white respectively. Therefore, the findings might not be generalizable to districts with more diverse student populations. In addition, the percent of students living below the poverty line were 10% and 16.3% respectively. As a result, the findings may not be generalizable to districts with higher levels of poverty.

The researcher used the Danielson FFT classroom observation instrument to collect quantitative data. Most districts in Idaho use this rubric for measuring teacher performance – those that do not are required to map their evaluation tools to the Danielson FFT. Therefore, the results of this study might not be readily applicable to those districts in Idaho using a different evaluation tool. Administrators in Idaho are required to become certified to use the Danielson FFT classroom observation instrument. They are also required to engage in calibration activities for recertification at least every five years. However, there can still be a degree of variation among certified evaluators within the framework. The calibration process between Danielson consultants illustrates this point. During the annual calibration process, two consultants watch a video-recorded lesson individually. Each consultant records their own evidence and determines a score for each component. Then they compare their evidence and ratings. In cases where the scores agree, there is no further discussion. However, if there is a disagreement about the rating, the consultants engage in a dialogue until they can agree. Dialogues regarding a single rating can last over an hour. If no agreement can be reached, a third consultant is brought in to break the tie. This illustrates that fact that there can be a difference in scores among certified Danielson evaluators. Therefore, the potential for inter-rater reliability between this study and a similar study may present a limitation to the reliability of the findings.

Lastly, the professional capacity of the Danielson evaluator was a limitation in this study. Specifically, the Danielson evaluator was not aware of the research questions. This was done intentionally so the evaluator would not know which group each sample video belonged to in an effort to reduce bias in the classroom observation scores. However, this limited the ability the evaluator had to engage with the teachers being evaluated to better understand their thought processes during their instruction.

Delimitations

The purpose of this study was to investigate the impact of lesson study on math teacher professional growth. The researcher limited the number of participants for the quantitative portion of the study to 20 due to the limitation of resources available to observe and analyze the video-recorded math lessons. The goal of the researcher was to obtain 10 teaching samples from teachers who had participated in lesson study 0-2 years and 10 teaching samples from teachers who had participated in lesson study 3-6 years.

The researcher selected Idaho for the study because the researcher had the opportunity to provide feedback to state agencies regarding the outcomes of state professional development programs. The state of Idaho is divided into six educational regions based on culture, geography, and economic base. Regions II and IV used lesson study as the primary method of delivering professional development to math teachers at the time of this research. The researcher selected Region II for the study because of the cooperation of the math specialist for the region. The researcher did not include participants from Region IV due to geographic constraints in obtaining participants. In addition, Regions II and IV in Idaho use slightly different models of lesson study. Specifically, participants in Region IV reteach a revised research lesson; whereas participants in Region II do not. By limiting the study to one region, the researcher was able to reduce the number of variables that could affect the outcomes. The following chapter outlines the results of the study.

Chapter IV

Results

Introduction

This chapter presents the results from this mixed-methods study. Quantitative results include data from the Danielson FFT classroom observation instrument (Danielson, 2007). Qualitative results include data from teacher focus group interviews, and one-on-one interviews with administrators. Details of the study design are also presented.

Quantitative Results

The researcher used quantitative methods to investigate the impact of lesson study on the professional growth of math teachers using the Danielson FFT classroom observation instrument (Danielson, 2007). The researcher video-recorded a 30-60-minute math lesson from 19 K-12 math teachers. A Danielson consultant was hired to score each video on components 2A, 2B, 3A, 3B, 3C, and 3D of the Danielson FFT. Each component was given a score of 1-4 according to the rubric contained in the framework (see Appendix I). The researcher used the Statistical Package for the Social Sciences (SPSS) version 27 to analyze the numeric data.

The researcher divided the sample scores ($N = 19$) into two groups. Group one contained scores from teachers who had participated in lesson study 0-2 years ($N = 11$). Group two contained scores from teachers who had participated in lesson study 3-6 years ($N = 8$). The researcher looked for outliers in each group by studying box plots for each of the six components, as well as the composite score. The box plots showed one outlier in Group 2. The teacher in the outlying case was not able to teach a typical math lesson at the time of the observation due to a disruption in the school day. Therefore, the researcher eliminated this case and proceeded with the analysis using the remaining 18 cases. Table 7 shows demographic data for participants in the two groups. Of note is the fact that both groups had similar average number of years teaching experience with an average difference of 0.6 years. Table 8 shows the classroom observation scores for the sample (*N* = 18). The following sections present the quantitative results for each instructional element analyzed.

Table 7

Demographics of Classroom Observation Independent Groups

Demographic	Group 1	Group 2
Elementary Teachers	10	5
Secondary Teachers	1	2
Years Teaching (Average)	15.8	16.4
Years Teaching (Range)	1-33	7-25
Years in Lesson Study (Average)	.73	5
Years in Lesson Study (Range)	0-2	3-6

Table 8

Scores From Danielson FFT Classroom Observation Instrument

Case No.	Years Taught	Years of Lesson Study	Component Scores						
			2A	2B	3A	3B	3C	3D	Average
1	5	0	3	2	3	2	1.5	2	2.25
2	1	0	3	3	4	4	4	3	3.50
3	32	0	3	3	3	2	2	2	2.50
4	24	1	4	3	3	4	4	4	3.67
5	30	1	4	4	3	3	3	4	3.50
6	8	2	3	4	3	3	3	4	3.33
7	2	2	3	4	3	3	3	3	3.17
8	27	2	2	2	2	2	1.5	2	1.92
9	3	2	2	3	2	2	3	3	2.50
10	22	2	3	2	2	2	1.5	2	2.08
11	9	2	4	4	4	4	4	4	4.00
12	11	3	4	4	3	4	4	4	3.83
13	18	5	4	3	3	4	4	4	3.67
14	17	5	3	3	3	4	4	3	3.33
15	25	5	3	3	3	4	3.5	4	3.42
16	7	5	3	4	4	4	3	4	3.67
17	25	6	4	4	4	3	4	4	3.83
18	12	6	4	3	4	3	4	4	3.67

Creating an Environment of Respect and Rapport (2A)

The researcher looked for trends in teachers' capacity to create an environment of respect and rapport by graphing the scores for component 2A according to how many years the participant had engaged in lesson study (see Figure 2). The graph showed a slight upward trend in scores for component 2A as the participants' experience with lesson study increased. The researcher used a Mann Whitney U test to determine if there was a statistically significant difference in scores between group one and group two. Distributions of the scores for component 2A for group one and group two were not similar, as assessed by visual inspection (see Figure 3). Therefore, the researcher analyzed the difference in mean rank scores between the groups. The null hypothesis was the mean rank of 2A scores is the same across both groups. Although group two had a slightly higher average, the 2A scores for group one (mean rank = 8.18) and group two (mean rank = 11.57) were not statistically significantly different, $U = 53.00$, $z = 1.453$, $p = .146$. This result was not sufficient to reject the null hypothesis. Therefore, there was no statistical difference in performance rating on component 2A for teachers with 0-2 years' experience with lesson study compared to teachers with 3-6 years' experience with lesson study.

Figure 2

Graph of 2A Scores by Lesson Study Years

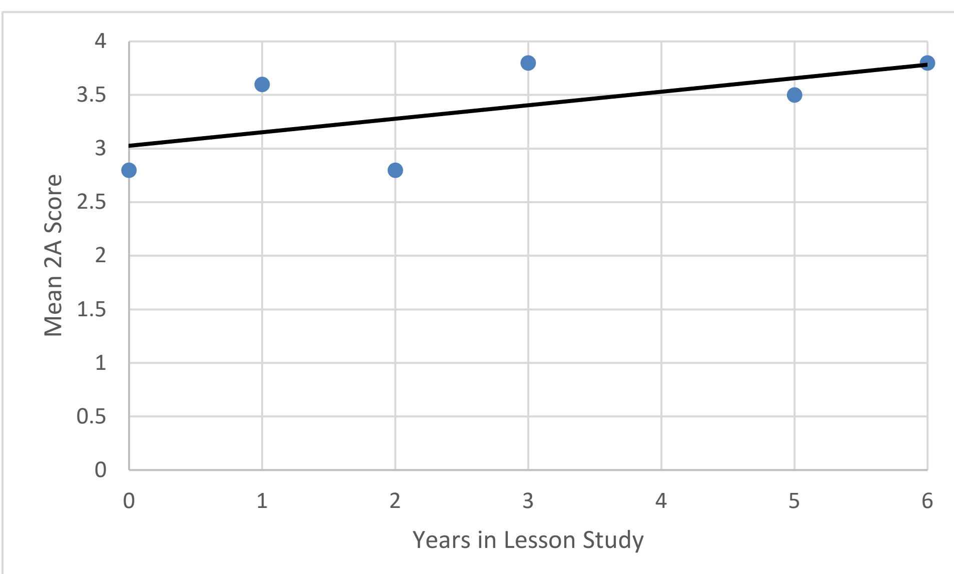
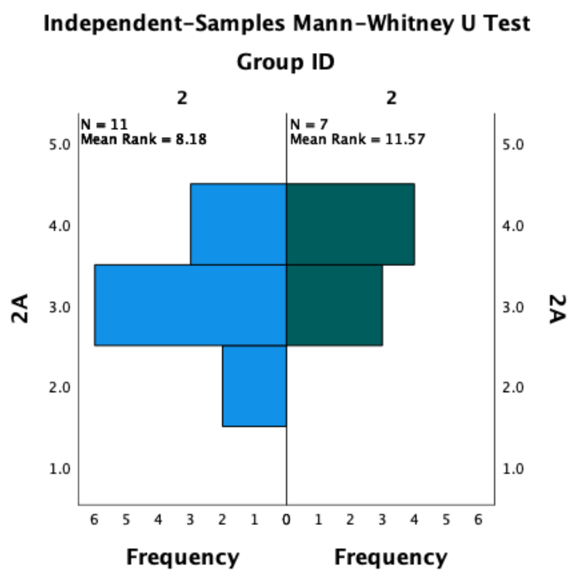


Figure 3

Distributions of 2A Scores for the Independent Groups



Establishing a Culture for Learning (2B)

The researcher looked for trends in teachers' capacity to establish a culture for learning by graphing the scores for component 2B according to how many years the participant had engaged in lesson study (see Figure 4). The graph showed a slight upward trend in 2B scores across the number of years in lesson study. The researcher used a Mann Whitney U test to determine if there was a statistically significant difference in scores between group one and group two. Distributions of the scores for component 2B for group one and group two were not similar, as assessed by visual inspection (see Figure 5). Therefore, the researcher analyzed the difference in mean rank scores between the groups. The null hypothesis was the distribution mean rank scores of 2B is the same across both groups. Although group two had a slightly higher average, the 2B scores for group one (mean rank = 8.73) and group two (mean rank = 10.71) were not statistically significantly different, $U = 47.00$, $z = .834$, $p = .404$. This result was not sufficient to reject the null hypothesis. Therefore, there was no statistical difference in performance rating on component 2B for teachers with 0-2 years' experience with lesson study compared to teachers with 3-6 years' experience with lesson study.

Figure 4

Graph of 2B Scores by Lesson Study Years

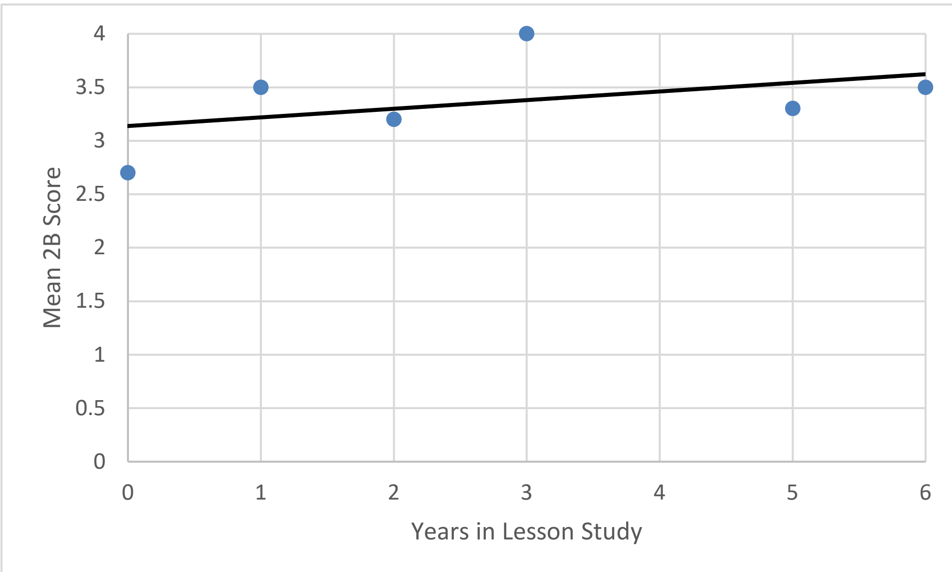
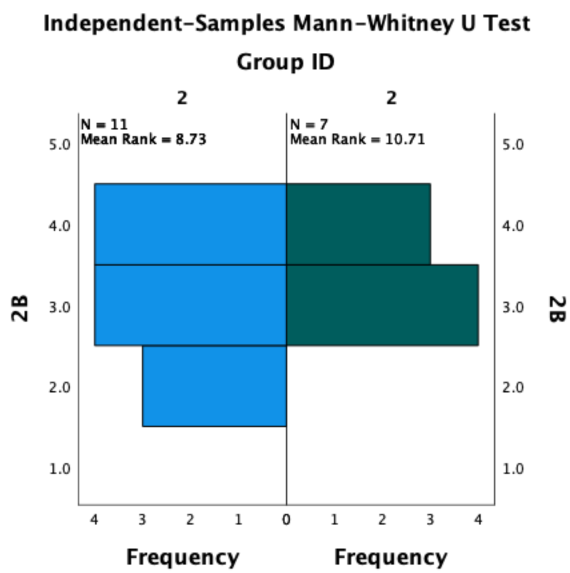


Figure 5

Distributions of 2B scores for the Independent Groups



Communicating with Students (3A)

The researcher looked for trends in teachers' capacity to communicate with students by graphing the scores for component 3A according to how many years the participant had engaged in lesson study (see Figure 6). The graph showed a slight upward trend in scores for component 3A as the participants' experience with lesson study increased. The researcher used a Mann Whitney U test to determine if there was a statistically significant difference in scores between group one and group two. Distributions of the scores for component 3A for group one and group two were not similar, as assessed by visual inspection (see Figure 7). Therefore, the researcher analyzed the difference in mean rank scores between the groups. The null hypothesis was the distribution mean rank scores of 3A is the same across both groups. Although group two had a slightly higher average, the 3A scores for group one (mean rank = 8.09) and group two (mean rank = 11.71) were not statistically significantly different, $U = 54.00$, $z = 1.565$, $p = .118$. This result was not sufficient to reject the null hypothesis. Therefore, there was no statistical difference in performance rating on component 3A for teachers with 0-2 years' experience with lesson study compared to teachers with 3-6 years' experience with lesson study.

Figure 6

Graph of 3A Scores by Lesson Study Years

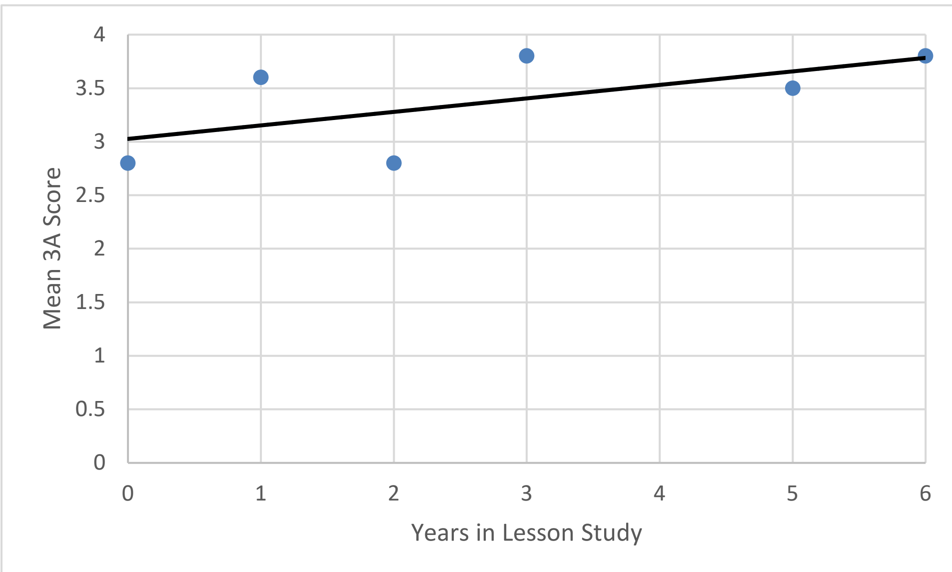
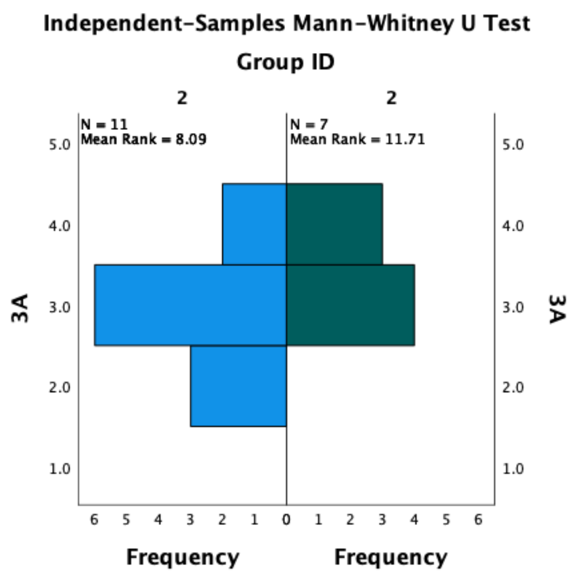


Figure 7

Distributions of 3A scores for the Independent Groups



Using Question and Discussion Techniques (3B)

The researcher looked for trends in teachers' capacity to use question and discussion techniques by graphing the scores for component 3B according to how many years the participant had engaged in lesson study (see Figure 8). The graph showed a steady upward trend in 3B scores as the participants' experience with lesson study increased. The researcher used a Mann Whitney U test to determine if there was a statistically significant difference in scores between group one and group two. Distributions of the scores for component 3B for both group one and group two were not similar, as assessed by visual inspection (see Figure 9). Therefore, the researcher analyzed the difference in mean rank scores between the groups. The null hypothesis was the distribution of mean rank scores for 3B is the same across both groups. The 3B scores for group two (mean rank = 12.64) were statistically significantly higher than for group one (mean rank = 7.50), $U = 60.50$, $z = 2.134$, $p = .033$. This result was sufficient to reject the null hypothesis. Therefore, teachers with 3-6 years' experience with lesson study had a statistically significantly higher performance rating on component 3B than teachers with 0-2 years' experience with lesson study.

Figure 8

Graph of 3B Scores by Lesson Study Years

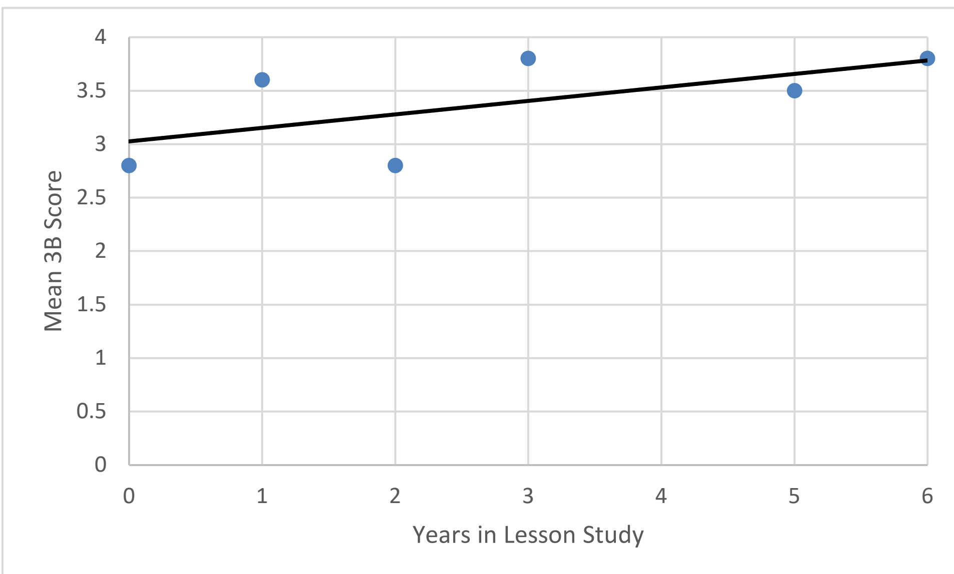
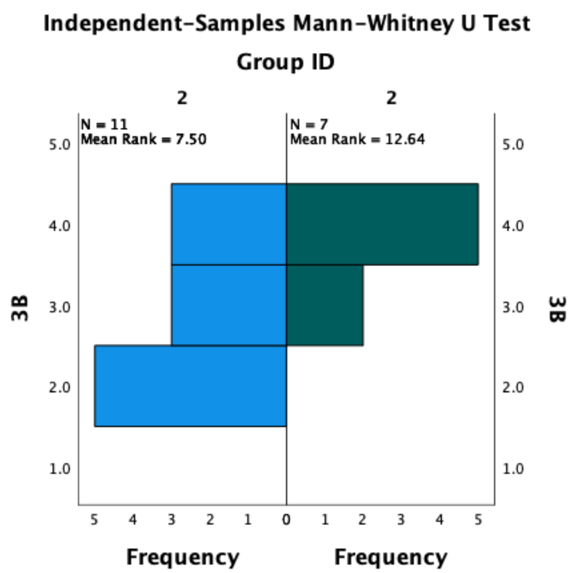


Figure 9

Distributions of 3B scores for the Independent Groups



Engaging Students in Learning (3C)

The researcher looked for trends in teachers' capacity to engage students in learning by graphing the scores for component 3C according to how many years the participant had engaged in lesson study (see Figure 10). The graph showed an upward trend in scores for component 3C as the participants' experience with lesson study increased. The researcher used a Mann Whitney U test to determine if there was a statistically significant difference in scores between group one and group two. Distributions of the scores for component 3C for both group one and group two were not similar, as assessed by visual inspection (see Figure 11). Therefore, the researcher analyzed the difference in mean rank scores between the groups. The null hypothesis was the distribution of mean rank scores for 3C scores is the same across both groups. The 3C scores for group two (mean rank = 12.79) were statistically significantly higher than for group one (mean rank = 7.41), $U = 61.50$, $z = 2.100$, $p = .027$. This result was sufficient to reject the null hypothesis. Therefore, teachers with 3-6 years' experience with lesson study had a statistically significantly higher performance rating on component 3C than teachers with 0-2 years' experience with lesson study.

Figure 10

Graph of 3C Scores by Lesson Study Years

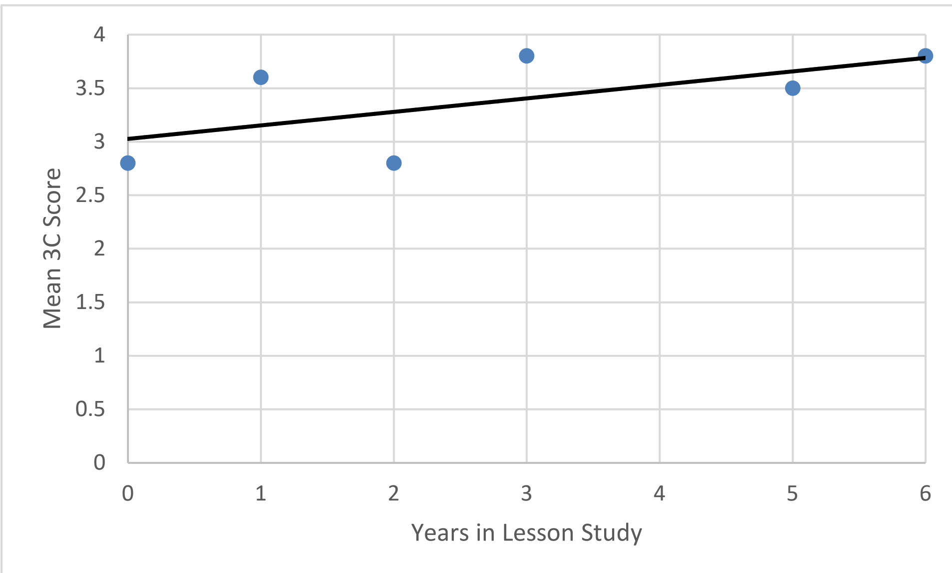
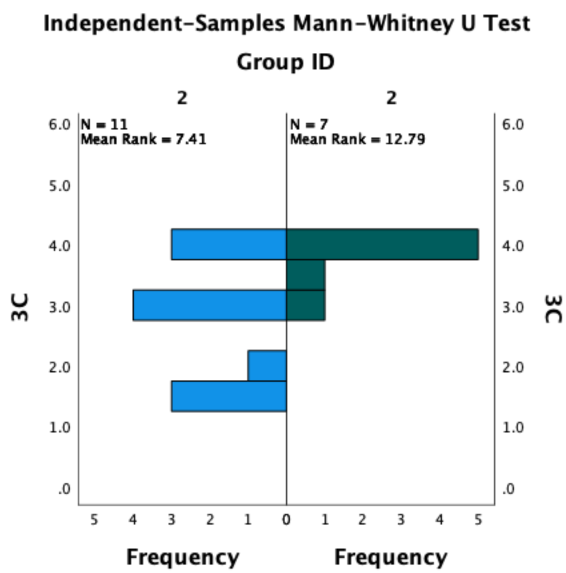


Figure 11

Distributions of 3C scores for the Independent Groups



Using Assessment in Instruction (3D)

The researcher looked for trends in teachers' capacity to use assessment during instruction by graphing the scores for component 3D according to how many years the participant had engaged in lesson study (see Figure 12). The graph showed a slightly upward trend in scores for component 3D as the participants' experience with lesson study increased. The researcher used a Mann Whitney U test to determine if there was a statistically significant difference in scores between group one and group two. Distributions of the scores for component 3D for both group one and group two were not similar, as assessed by visual inspection (see Figure 13). Therefore, the researcher analyzed the difference in mean rank scores between the groups. The null hypothesis was the distribution of mean rank scores for 3D is the same across both groups. The 3D scores for group two (mean rank = 12.50) were statistically significantly higher than for group one (mean rank = 7.59), $U = 59.50$, $z = 2.114$, $p = .034$. This result was sufficient to reject the null hypothesis. Therefore, teachers with 3-6 years' experience with lesson study had a statistically significantly higher performance rating on component 3D than teachers with 0-2 years' experience with lesson study.

Figure 12

Graph of 3D Scores by Lesson Study Years

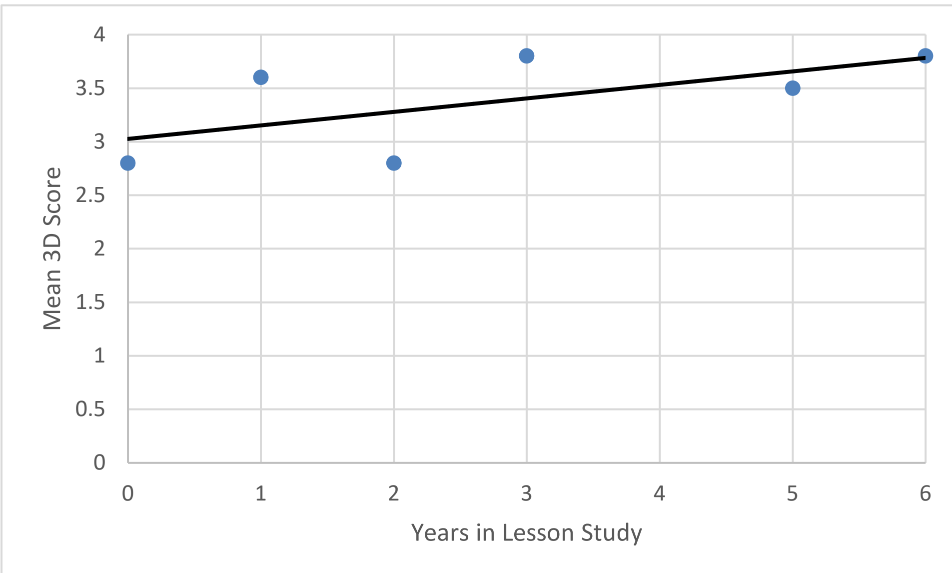
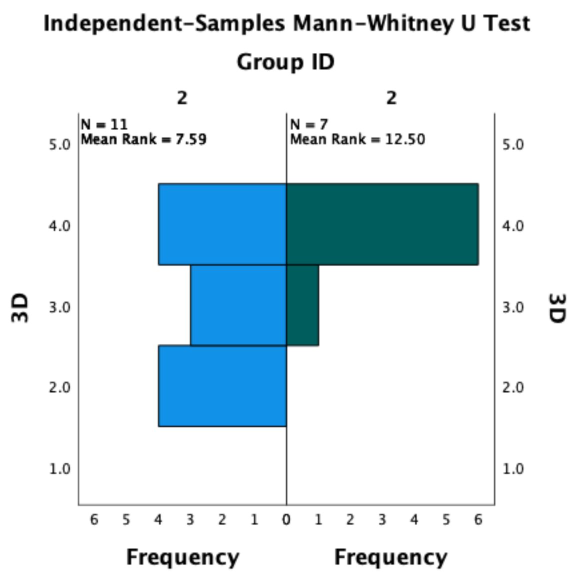


Figure 13

Distributions of 3D scores for the Independent Groups



Qualitative Results

Focus Group Interviews

The researcher used qualitative methods to determine math teachers' perceptions of the impact lesson study has on their ability to engage students in learning. The researcher conducted six focus group interviews with 27 K-12 math teachers at schools that had participated in lesson study for three or more years. The researcher wanted to include as many teachers as possible in the focus group interviews. All teachers who had participated in at least one year of lesson study were invited to participate. Table 9 provides demographic information for the focus group participants. The interview data was not segregated by number of years' experience with lesson study due to the low number of participants who had engaged in lesson study for 3-6 years. Interview participants were identified in the transcripts using an alias and together they presented their perspectives of the impact of lesson study on student engagement regardless of how many years they had participated in the lesson study program.

Table 9

Focus Group Participant Demographics (N = 27)

Demographic	
Elementary Teachers	25
Secondary Teachers	2
Years Teaching (Average)	11.4
Years Teaching (Range)	1-30
Years in Lesson Study (Average)	2.8
Years in Lesson Study (Range)	1-6

The first question asked participants to share their perceptions regarding the impact of lesson study on the learning culture of their math classrooms. Five additional questions explored various aspects of student engagement contained in Domain 3 (Instruction and Assessment) of the Danielson FFT (Danielson, 2007). At the conclusion of the interview, the teachers were invited to share their perceptions of the impact lesson study had on student achievement and to share any additional thoughts on lesson study in general. The resulting codes and themes for each interview question are presented below along with sample responses.

Focus Group Interview Question 1. The researcher asked focus group participants how lesson study had impacted the learning culture in their classrooms during math instruction. Table 10 summarizes the process codes for question one along with the frequency of each code in the data corpus.

Table 10

Impact on Learning Culture

Process Code	Frequency
Teacher Behaviors	
Normalizing Mistakes	8
Focusing on Learning Process	5
Modeling the Role of Mathematicians	4
Student Behaviors	
Feeling Safe	5
Gaining Confidence	4
Taking Ownership	3

Note. The process codes are divided between teacher behaviors and student behaviors. The frequency indicates the number of occurrences in the focus group interview data.

The teachers described a change in the culture of their classrooms to a place where mistakes are considered part of the learning process. One participant said it this way:

> Before I started lesson study, math always had a right and wrong answer, always. And one of the things that lesson study has built into, with my students, is that they are okay having the answer that is not the correct answer always.

Another participant added:

> It's like we're all here to learn and we make mistakes, and I'll point that out, too. I'm glad that you made that mistake because this is a mistake that everybody makes at some point in time, and now, we can see it and think about it and see why it's a mistake.

Most participants explained they have learned to focus math instruction on the learning processes rather than the final answer. One participant explained, "It's not about answer-getting anymore, it's more about learning and the journey to get there rather than the destination." Another added, "We're moving toward how did you get there? What strategy did you use? Convince me that that will work, show me." The participants felt this more process-oriented approach to math instruction has created a safe learning environment. One participant described their class as a place where "the kids feel safe, and they can talk about it (math) and share their ideas." Another participant said:

> I'd definitely say it feels like a safer environment. It adds to what we've been trying to accomplish in the classroom as a community and having everybody have that opportunity to, as I call it, show what you know or show what you've learned versus 'is this the right answer?'

The teachers believed that those students who traditionally identify as not good at math are gaining the confidence to participate. For instance, "in the past, you would see students who were like, 'I'm not a mathematician, I can't do this.' And…there's much, much less of that." Some teachers shared that lesson study provides opportunities for students to learn how to take ownership of their learning. One participant explained, "I feel like the pressure has been taken off the teacher and put back onto the students in the best way possible through these lesson studies because they take ownership over their learning." Another summed it up this way, "They're taking ownership and they're learning, and they feel like they're capable." In summary, the majority of the teachers felt their experiences with lesson study have helped them create a safe learning environment by normalizing mistakes, focusing on the process of learning, and modeling the role of mathematicians. As a result, the teachers perceived that their students are gaining the confidence to take intellectual risks resulting in increased ownership of the learning.

Focus Group Question 2. The researcher asked participants how lesson study has impacted their students' involvement in the explanation of mathematical content. Table 11 summarizes the process codes for question 2 along with the frequency of each code.

Table 11

Impact on Student Engagement in Explanations of Content

Pattern Code	Frequency
Teaching Each Other	5
Explaining Thinking	3

Note. The frequency indicates the number of times the code appeared in the teacher focus group interview data.

The participants explained that the shift towards a more process-oriented approach to math instruction has created more opportunities for students to explain and justify their thinking. One teacher described her teaching experience as "putting [students] in a position where they have to justify, have to explain it to each other." Teachers shared that the students often work collaboratively to discover solutions to mathematical problems. As a result, the teachers believed students spend more time explaining their solutions to the class. One teacher described her experiences this way, "A lot of times kids will come up with solutions that I've never thought about. Instead of shying away from it, I acknowledge it – 'Wow, I've never done it that way, can you explain more'?"

One theme that emerged frequently was that students are taking ownership of their learning in the class and are taking more opportunities to teach each other. One participant explained, "They are up there teaching the other kids and we're just back listening and maybe asking for clarification once in a while, but they're the ones explaining, they turn into the teacher." Another participant put it this way, "I'm learning new ways to empower the students to be little teachers." In summary, the participants believed lesson study has enabled them to engage students in the learning by providing them opportunities to explain their thinking and teach each other.

Focus Group Question 3. The researcher asked focus group participants how lesson study has impacted the mathematical discourse in their classrooms. This includes teacher-to-student discourse through questioning techniques and student-to-student discourse through discussion techniques. Table 12 summarizes the process codes for question three along with the frequency for each code.

Table 12

Impact on Student Engagement in Mathematical Discourse

Process Code	Frequency
Teacher Behaviors	
Asking Higher Level Questions	8
Providing Wait Time	3
Student Behaviors	
Engaging in Discourse	23

Note. The process codes are divided between teacher behaviors and student behaviors. The frequency indicates the number of occurrences in the focus group interview data.

The responses suggested a shift towards deeper questions leading to mathematical discussions. One participant explained it this way, "I'm able to actually pose questions that are going to lead to those discussions rather than questions that are leading to an answer." Another participant said lesson study "makes you think about it and get a lot better at [asking] advancing questions versus assessment questions…That's not something I would have ever thought about until doing lesson study."

In conjunction with asking high-level questions, the teachers indicated they have learned how discussions can be stimulated by providing students with sufficient wait time. One teacher said, "It's really hard as a teacher, sometimes our first instinct is to jump right in there and help them. But we've learned from [lesson study]…you have to have the wait time." The participants also felt they have learned how to facilitate mathematical discussions by teaching sentence starters such as, "I agree because," "I disagree because," or "I would like to add." As a result, the participants described their classrooms as places where students are learning to engage in mathematical discourse. One teacher explained, "They're comfortable talking with a group without a teacher even needing to stand there or to ask them to do that, they do that on their own."

The teachers shared that student engagement in mathematical discourse has helped them establish a culture where all voices are valued. One participant explained, "They're learning not just to listen to the teacher as the authority figure, but that their peers have really valuable things to say." Many participants observed their students respectfully disagreeing as they debate mathematical reasoning. One participant shared, "The best times are when they start arguing. When they have a disagreement about it, and they start trying to convince the other person that they had it right." In summary, participants felt lesson study has increased the engagement of their students in mathematical discourse as the teachers have learned to ask more open-ended questions and provided the time for students to engage in discourse including agreeing, disagreeing, and critiquing the mathematical reasoning of their classmates.

Focus Group Question 4. The researcher asked focus group participants how lesson study has impacted student engagement in the learning. Table 13 summarizes the process codes for question four along with the frequency for each code.

Table 13

Impact on Student Engagement in Learning

Process Code	Frequency
Discovering Solutions	29
Persevering in Complex Tasks	10
Collaborating	5

Note. The frequency indicates the number of occurrences in the focus group transcripts.

One of the major themes in the data was that the participants believed their experience with lesson study has shifted their philosophy of teaching math to a more discovery-based approach. This means their students are free to discover their own solutions to mathematical problems rather than being taught a standard algorithm. As a result, they felt their students are much more engaged in the learning. They described their classrooms as noisy and fun environments where students persevere in working towards mathematical outcomes. One participant noted, “It gets loud, and they get messy and there’s paper, like today we were cutting strips of paper and it was all over, but it’s fun and you see them, the wheels are turning.” The participants also felt their students were learning to persevere in complex mathematical tasks for long periods of time. “It’s so much more exciting to teach them…it’s more engaging…it’s amazing, honestly amazing, that a fourth-grade classroom could be actively doing math for an hour-and-a-half.” The teachers felt this approach to math instruction engages students at all levels: “Now, when we do math lesson study, even though we want the same outcome, everyone's attacking it in a different way, so then they all have an entry point [regardless] of what their background is and what they know."

The teachers also believed that discovery learning has facilitated student collaboration in problem solving. One teacher said, "They're coming up with those things and [it] is much more student directed." Another participant said, "[It's] a lot more social, it's more of a collaborative math experience." The participants provided evidence that students are discovering their own mathematical processes as they work together to solve problems. One participant described her experience this way, "I would say [this] just brings joy…this is what we want to see…[them] discovering things." In summary, the teachers felt their shift towards a more discovery-based approach to learning has allowed them to engage students at all levels in collaborative efforts to discover solutions to authentic mathematical tasks.

Focus Group Question 5. The researcher asked participants how lesson study has impacted their ability to use assessment during instruction. Table 14 summarizes the process codes for question five along with the frequency for each code.

Table 14

Impact on Student Engagement in Assessment

Process Code	Frequency
Identifying Growth Opportunities	6
Assessing Student Thinking	4

Note. The frequency indicates the number of occurrences in the focus group interview data.

The participants indicated they can assess student thinking more readily as students make their thinking visible. One participant said, "I'm able to more quickly see where they're at individually." The teachers felt they can readily identify next steps for individual students as they make their thinking visible. One participant explained, “[It’s] been nice to be able to push them along a trajectory where you have your starting point, [and determine] what’s that next step?” In summary, the participants felt lesson study has taught them how to make their students’ thinking more visible, which has helped them assess and identify the next steps for their students.

Focus Group Question 6. The researcher asked participants how lesson study has impacted their students’ ability to self-assess their progress. The Danielson FFT includes student self-assessment as evidence of a distinguished classroom (Danielson, 2007). Four participants commented on self-assessment. The following quote is representative of the responses: “I’ve struggled with that part because I haven’t given that (self-assessment) to them.” In summary, the participants could not provide any examples of the impact of lesson study on student self-assessment in their classrooms.

Focus Group Question 7. The researcher asked participants if they see any evidence that lesson study can impact student achievement in math. Table 15 summarizes the process codes for question seven along with the frequency for each code.

Table 15

Impact on Student Outcomes

Process Code	Frequency
Increasing Problem-Solving Skills	5
Aligning to Traditional Assessments	5
Understanding at Deeper Level	4
Increasing Number Sense	2

Note. The frequency indicates the number of occurrences in the focus group interview data.

The teachers had a favorable opinion on the impact of lesson study on student outcomes such as increased number sense and increased problem-solving skills. This is evidenced by comments such as, “I think they’re building that strong number sense,” “I think they’re getting better at the reasoning and problem solving,” and “These are strategies that we’re teaching kids to be thinkers.” As a result, the teachers felt their students have a deeper understanding of the math. One teacher said, “It’s a way better way of teaching, in my opinion. I think kids actually learn, it’s not just memorizing for the short period of time to pass the test and then forget it.” However, the teachers felt traditional assessments are not aligned to the process-oriented approach to math instruction they are learning during lesson study. One participant explained:

> If we are wanting to encourage students to verbalize their thinking and if we’re encouraging them to persevere and try something, even if it’s not the thing that’s going to work out, and be willing to take risks and all these other things that we want them to do in the classroom, and then we give them a paper test where they have to answer a whole bunch of questions and it’s either right or wrong. It doesn’t really jive together very well.

In summary, the teachers felt lesson study has led to improved student outcomes such as thinking and reasoning skills, but they are not seeing that change represented on standardized tests.

Focus Group Questions 8 and 9. The final questions provided participants the opportunity to share any other thoughts about their experiences with lesson study. Table 16 summarizes the process codes for the open interview questions.

Table 16

Focus Group Open Response Codes

Process Code	Frequency
Learning Through Lesson Study	18
Transferring Skills across Content Areas	10

Note. The frequency indicates the number of times the code appears in the focus group interview data.

The teachers described their lesson study experiences with phrases such as "incredibly hard," "intense," and "uncomfortable." Yet, the consensus was that lesson study has had a greater impact on their practice than other professional development experiences such as conferences. One participant explained, "I feel like the lesson study… is probably one of the most valuable things just because we get to actually do it instead of just hearing about it." When compared to other professional development experiences, the teachers described lesson study as a rich learning experience that creates "teacher changing, classroom changing kinds of stuff." Additionally, participants felt that the learning culture teachers have created during their math lessons has permeated their classrooms across all content areas. One participant said:

> I would say across the board, whether it's math or reading, whatever subject we're working on, I do see a lot more student engagement and ownership. They're learning how to have those respectful conversations…and they're…leading a lot of the lessons.

Responses indicated that teachers are transferring their developing skills across different curriculums and across all content areas, especially their question and discussion techniques. One participant described:

> You just become a better questioner all over and it helps in every subject area that you

> teach…And so that is the benefit, I think, of lesson study is that not only has it worked in math, it's bled over into a lot of other subject areas. And in teaching overall.

The teachers credited the success of their lesson study program to the strength of their facilitator:

> I don't think it would have been as successful if [he] wasn't there putting in countless hours outside of lesson study, digging up the research that we were going to use in the lesson studies and doing his own research so that he had that background of…a large wealth of resources that he could tap into to help us make it work.

In summary, the teachers described lesson study as an intense process that has had significant impact on their practice. One participant summed it up this way, "I mean, it's really digging in and figuring some things out and teaching at least, for me, has changed a lot."

Administrator Interviews

The researcher used qualitative methods to determine administrator perceptions of the impact of lesson study on the professional growth of their teachers using the Danielson FFT classroom observation instrument (Danielson, 2007). The researcher conducted one-on-one semi-structured interviews with one secondary and three elementary principals at schools that had participated in lesson study for three or more years. Table 17 provides the demographic information for the administrator participants.

Table 17

*Administrator Interview Participant Summary (*N *= 4)*

Demographic	
Elementary Administrators	3
Secondary Administrators	1
Years Administrating (Average)	6.5
Years Administrating (Range)	3-15
Years School in Lesson Study (Average)	5.3
Years School in Lesson Study (Range)	3-6

The interviews began with two general questions regarding participant perceptions of the biggest impact of lesson study on math instruction and their math teacher's professional growth. The researcher then asked participants six questions aligned to specific components of teacher practice contained in the Danielson FFT. The administrators were then invited to share their perceptions of the impact of lesson study on student achievement and to share any other remaining thoughts. The resulting codes and themes for each interview question are presented below along with sample responses.

Administrator Interview Question 1. The researcher asked administrators what they considered to be the biggest impact of lesson study on math instruction. Table 18 summarizes the pattern codes for question one along with the frequency of each code in the data.

Table 18

Biggest Change in Math Instruction

Pattern Code	Frequency
Questioning and Discussion	2
Complex Tasks	2
Discovery Learning	2

Note. The frequency indicates the number of times the code appears in the response to question one.

Two of the participants mentioned purposeful questioning and discussion techniques as the biggest changes to teacher practice. One administrator said, "I would say that's the number one thing, just the questioning, and then how they get kids to discuss." In addition, two participants mentioned an increased engagement of students in more complex mathematical tasks. The administrators explained, "[teachers] help kids think through and persevere in solving some of those big math tasks," and, "They're understanding that the levels of engagement in those real-world tasks that build on each other is where the learning is at." Finally, the data suggested a shift in math instruction towards a more discovery learning model of pedagogy. For example, one administrator stated, "The students have more of an opportunity to discover their learning rather than the traditional algorithm," and another added, "We don't give the student the answer, but we allow them to work their way towards the answer." In summary, the administrators identified improved question and discussion techniques, engagement in complex mathematical tasks, and a shift towards discovery learning as being the biggest changes to math instruction.

Administrator Interview Question 2. The researcher asked administrators to share their perceptions of the impact of lesson study on their math teachers' professional growth. Table 19 summarizes the pattern codes for question two along with the frequency of each code in the data.

Table 19

Biggest Impact on Teacher Professional Growth

Pattern Code	Frequency
Student-Centered Learning	10
Increased Pedagogical Strategies	5
Differentiated Instruction	5

Note. The frequency indicates the number of times the code appears in the administrator interview data.

The participants indicated they have seen a change in their teachers' philosophy towards how kids learn math. Administrators indicated their teachers have shifted from rote-practice instruction to lessons built around problem solving and real-world tasks. One administrator summed it up this way, "[teachers are] changing their practice as a result of changing their philosophy about how kids learn." Specifically, "I'm seeing teachers move away from that traditional idea that math learning is linear." The administrators saw less lecturing, and more time spent with students constructing their knowledge. One participant described his class observations this way, "I've seen…a lot less sit in a row and get the information and don't talk." Administrators also shared their teachers are increasing their repertoire of pedagogical strategies and becoming willing to take the risks necessary to try new methods of teaching. This is best represented by the following excerpt, "I think the lesson study gives multiple methods to look at things and helps teachers gain that pedagogy to do that." Lastly, two administrators indicated lesson study has enabled their teachers to differentiate instruction more regularly. One administrator said it has enabled teachers "to differentiate their instruction and not just lean on one model." In summary, the participants believed teachers have grown professionally by changing their practice to student-centered learning, increasing their pedagogical strategies, and differentiating instruction more.

Administrator Interview Question 3. The researcher asked the participants how the learning culture of their math classrooms has been impacted by lesson study. This aligns to component 2B (Establishing a Culture for Learning) from the Danielson FFT (Danielson, 2007). Table 20 summarizes the pattern codes for question three along with the frequency of each code in the data.

Table 20

Impact on Learning Culture

Pattern Code	Frequency
Safe Learning Environment	11
Student Buy-In	5

Note. The frequency indicates the number of times the code appears in the administrator interview data.

The administrators indicated their teachers' math classrooms have transformed into safe learning environments where students are invited to take intellectual risks as teachers normalize error as part of the learning process. In other words, teachers are allowing students to make mistakes as they work to figure things out. This is evidenced in comments such as "This is safe, I want to take you these risks, this is how we learn," and "failure's just a part of the process." As a result, administrators believed students are more confident to share their thoughts and ideas.

Administrators also shared they believed this has included more students in the learning. They explained that in the past, just those kids with the correct solution would share their strategies. Now, multiple strategies are encouraged, and more students are confident to share their ideas. Administrators felt the teachers themselves are also seen as learners as they try new strategies and learn alongside the students. One administrator described it this way, "One of the best [things] I've seen is willingness to take risks in their pedagogy…[the] willingness to try different strategies." According to administrators, this learning environment has increased student buy-in with the learning. For example, one administrator stated, "We're getting that buy-in from students and they're engaging now, academically, with the content. Where before, they were being unsuccessful right off the bat and checking themselves out of the learning." Another participant explained it this way:

> They feel like they're a part of the learning now…it isn't something that's being done to them, it's something that they're actually engaging in and driving. And so, we're seeing them investing in the learning and taking responsibility for some of the learning, too.

In summary, the participants indicated they believed lesson study has impacted the learning culture of their math classrooms by facilitating safe learning environments where students are taking intellectual risks and assuming responsibility for the learning.

Administrator Interview Question 4. The researcher asked the participants how lesson study has impacted the teachers' explanations of mathematical content. This aligns to component 3A (Communicating with Students) from the Danielson FFT (Danielson, 2007). In reviewing the codes that emerged, there were no administrator responses that provided evidence that administrators believed lesson study had any impact on teacher explanations of mathematical content.

Administrator Interview Question 5. The researcher asked the participants how lesson study had impacted the role of students in the explanations of mathematical content. This aligns to component 3A (Communicating with Students) from the Danielson FFT that describes a distinguished classroom as one where students take responsibility to explain the content to their classmates (Danielson, 2007). Table 21 shows the frequency of this code in the data.

Table 21

Impact on Student Explanations of Content

Pattern Code	Frequency
Increased Student Explanations	7

Note. The frequency indicates the number of times the code appears in the administrator interview data.

Administrators believed teacher involvement with lesson study has increased the role of students in mathematical explanations. For example, one administrator noted, “I constantly see that when I walk into a math lesson that students are explaining how they got there, it’s not the teacher necessarily explaining how to do it, it’s the students explaining.” The administrators specifically mentioned the students are explaining their strategies, their solutions, and their mathematical reasoning. Administrators also noticed that the students are asking each other for help rather that the teacher: “Kids are asking partners, like, how’d you get this?” In summary, the participants indicated they believed lesson study has facilitated an increased role of students in the explanation of mathematical content to their classmates.

Administrator Interview Question 6. The researcher asked participating administrators how lesson study had impacted student discourse during math instruction. This is the essence of component 3B (Using Question and Discussion Techniques) from the Danielson FFT (Danielson, 2007). Table 22 summarizes the pattern codes for question six along with the frequency of the code in the data.

Table 22

Impact on Question and Discussion Techniques

Pattern Code	Frequency
Increased Student Discourse	7
Higher Level Questions	6

Note. The frequency indicates the number of times the code appears in the administrator interview data.

Administrators explained that students are being asked to talk through their solutions with each other and with the class as a whole. Comments such as, "we can…have that conversation and a lot of learning comes out of that," demonstrated the increased reliance on student discussions in the learning process. The administrators also indicated students are explaining and justifying their thinking and challenging one another's thinking. For example, one administrator commented, "You've got a kid saying, 'Well, I disagree with that,' which…kids are learning [is] okay." Another administrator summed it up this way, "They listen and then they might have a rebuttal argument for their thought, and it is a really good, powerful discussion that is had." In addition, the participants noticed their teachers asking higher-level questions. For example, one administrator said, "Teachers are asking questions that deepen the learning depending on where that child is coming to the table." In summary, all the administrator participants believed lesson study has created an increased amount of mathematical discourse and higher-level questioning during math instruction.

Administrator Interview Question 7. The researcher asked the participants to share their perceptions of how lesson study has impacted the engagement of students in the learning process. This is the essence of component 3C (Engaging Students in Learning) from the Danielson FFT (Danielson, 2007). Table 23 summarizes the pattern codes for question seven along with the frequency of each code in the data.

Table 23

Impact on Student Engagement

Pattern Code	Frequency
Problem-Based Learning	10
Support of Productive Struggle	7

Note. The frequency indicates the number of times the code appears in the administrator interview data.

In general, the participants believed student engagement has increased as instruction has shifted from the drill and kill approach to a more contextualized real-world problem-solving approach. One administrator said is this way, “So you see that they’re not given 18 problems to solve, it’s one big task that they just keep building on.” The participants mentioned student engagement has increased as students are given the opportunity to discover their own solutions to problems. One participant said, “so the students have more of an opportunity to discover their learning rather than the traditional algorithm.” Another mentioned, “we don’t give the student the answer, but we allow them to work their way towards the answer.” As a result, administrators believed multiple strategies are encouraged, and more students are confident to share their ideas. The participants also described their math classrooms as places where students are encouraged to persevere in problem solving, and where teachers are becoming more comfortable letting their students struggle. One participant described it this way, “they help kids think through and persevere in solving some of those big math tasks that they’re given.” In summary, the participants believed lesson study has increased the engagement of students in learning as they persevere in discovering solutions to complex mathematical tasks.

Administrator Interview Question 8. The researcher asked the participants to share their perceptions of how lesson study has impacted their teachers’ ability to collect evidence of student learning. This aligns to component 3D (Using Assessment in Instruction) from the Danielson FFT (Danielson, 2007). Table 24 summarizes the pattern codes for question eight along with the frequency of each code in the data.

Table 24

Impact on Using Assessment in Instruction

Pattern Code	Frequency
Need for Summative Assessments	7
Increased Evidence of Learning	6

Note. The frequency indicates the number of times the code appears in administrator interview data.

All four administrator participants felt lesson study has improved the opportunity for teachers to formatively assess where their students are at. One participant explained, “I think it offers more check-in because when students are explaining their thinking, then that is formative assessment.” Another said, “There’s times I’ve heard them say, ‘Man, I didn’t realize these kids really didn’t know that,’ or, ‘I didn’t realize how much they actually knew.’” However, the participants described a need to understand and develop new summative assessments to measure student learning, which is more aligned to a discovery-based approach to math instruction. One participant asked, “How can we combine all that stuff to show that our students are making progress?” Another asked, “What artifacts do they have as evidence of that [discovery] learning?” In summary, the participants felt there is an increased opportunity for teachers to formatively assess the thinking of their students, but they are not sure if that learning is being assessed on traditional summative assessments.

Administrator Interview Question 9. The researcher asked the participants to share any evidence that lesson study with teachers can impact student achievement. Table 25 summarizes the pattern codes for question nine along with the frequency of each code in the data.

Table 25

Impact on Student Achievement

Pattern Code	Frequency
Long-term Understanding	2
Growth on Standardized Tests	2
No Growth on Standardized Tests	2

Note. The frequency indicates the number of times the code appears in response to question nine in the administrator interview data.

Two administrators indicated they have seen improvement in students’ ability to think through mathematical problems and to explain their thinking. As a result, they believed their students have a deeper understanding of the math. As one participant put it, “I think it is beneficial because what I’ve seen is it equates to more long-term understanding of the math, rather than the memorization, which tends to get forgotten.” However, perceptions of the impact of lesson study with teachers on standardized test scores were mixed. One school experienced quite a bit of growth on ISAT scores during the five years they have participated in lesson study.

The administrator at this school explained, "Our sixth graders have consistently been at the state average or right below, and we were 17% above the state average this year." However, other schools have not experienced growth on standardized tests. One participant shared:

> When we looked at that based on five years ago when we weren't doing the lesson study and today, are we really seeing any sort of growth in the student's math abilities? And the short answer is well, not really.

In summary, the participants believed their engagement with lesson study has created better mathematical thinkers, but there is no consistent evidence this has translated to higher scores on standardized tests.

Administrator Interview Question 10. At the conclusion of the interview, the researcher invited the participants to share any other experiences with lesson study that they felt would be beneficial for the researcher to know. Table 26 summarizes the pattern codes for question eight along with the frequency of each code in the data.

Table 26

Administrator Interview Open Codes

Pattern Code	Frequency
Barriers to Success	12
Importance of Knowledgeable Other	7

Note. The frequency indicates the number of times the code appears in the administrator interview data.

Two main themes resulted from this open-ended discussion. The first is that there can be many barriers to the success of a lesson study program. The researcher identified seven different barriers shared by the administrators as follows:

1. Lesson study asks teachers to be vulnerable.
2. Discovery learning is still difficult for the lowest-level students.
3. Teachers do not like to be out of their classrooms for lesson study.
4. Lesson study requires a trusting school culture.
5. Discovery learning doesn't align to traditional assessments.
6. Some teachers can be resistant to change.
7. Student trauma interferes with their ability to learn regardless of teaching.

The second theme from question ten related to the importance of the role of the person facilitating the lesson study. In Japanese lesson study, this person is referred to as the Knowledgeable Other (KO). The KO facilitates the lesson study process by guiding the research of the literature, providing feedback on the research lesson and data collection plan, and overseeing the post lesson discussion (Lewis et al., 2019; Lomibao, 2016; Seleznyov, 2018; Takahashi & McDougal, 2016). The administrators in this study credited the success of their lesson study programs to the strength of the KO working with their teachers. For example, one participant said it this way, "I credit…[him] a lot for that shift in culture because of the way he was able to engage the staff." In summary, the participants discussed potential barriers to the success of a lesson study program and the importance of the role of the facilitator.

Research Question Results

Research Question 1. The researcher used scores from the Danielson Framework for Teaching (FFT) classroom observation instrument to answer the first research question: What is the impact of lesson study on math teachers' professional growth using the Danielson FFT classroom observation instrument? The researcher compared classroom observation scores between teachers who had participated in lesson study 0-2 years and those who had participated in lesson study 3-6 years on six components from the observation instrument. Due to the small sample size, the researcher used the non-parametric Mann Whitney U test to determine if there was a statistically significant difference in mean rank scores between the independent samples. Table 27 summarizes the outcomes for each instructional component analyzed. The results indicated there was not a statistically significant difference in mean rank scores in components 2A, 2B, and 3A. However, teachers who had engaged in lesson study longer had statistically significant higher mean rank scores in components 3B, 3C, and 3D.

Table 27

Summary of Quantitative Results

Hypothesis Test Summary				
Component	Null Hypothesis	Mann-Whitney U Test Statistic	Sig.[a,b]	Decision
2A	The distribution of 2A scores is the same across both groups.	53.0	.146	Accept the null hypothesis.
2B	The distribution of 2B scores is the same across both groups.	47.0	.404	Accept the null hypothesis.
3A	The distribution of 3A scores is the same across both groups.	54.0	.118	Accept the null hypothesis.
3B	The distribution of 3B scores is the same across both groups.	60.5	.033	Reject the null hypothesis.
3C	The distribution of 3C scores is the same across both groups.	61.5	.027	Reject the null hypothesis.
3D	The distribution of 3D scores is the same across both groups.	59.5	.034	Reject the null hypothesis.

Notes. [a]The significance level is 0.05. [b]The asymptotic significance level is displayed.

Research Question 2. The researcher used qualitative data from teacher focus group interviews to provide insight into the second research question: What are math teachers' perceptions of the impact lesson study has on their ability to engage students in learning as described by the Danielson FFT? Table 28 shows the codes that are aligned to the Danielson FFT with the highest frequency in the data corpus.

Teacher participants believed they had increased the engagement of students in the learning by normalizing mistakes as part of the learning process. As a result, they felt their students feel safe and are gaining the confidence to take intellectual risks. In addition, teachers believed the students are taking ownership of the learning and the lessons have become more student led. The teachers also indicated they have improved their ability to engage their students in mathematical discourse. Specifically, they have learned to ask higher-level questions that lead to student-led discussions. As a result, teachers perceived the students have become comfortable explaining their mathematical thinking to their classmates. Teachers also believed students have learned how to communicate as mathematicians including how to respectfully disagree and critique mathematical thought.

Lastly, participants perceived that student engagement had increased through the implementation of discovery learning activities. The teachers explained they have learned to design their math instruction around complex, real-world tasks where the students are not given the solutions beforehand. Rather, their students discover mathematical processes as they persevere in solving authentic tasks. Since the students are free to attack the problems from all different angles, teachers believed even the lowest performing students have an entry point to the assignment. The teachers described an increased level of student engagement for most students in the learning.

Table 28

Highest Frequency Focus Group Interview Codes

Descriptive Code	Danielson Component	Frequency
Discovering Solutions	3C	29
Engaging in Discourse	3B	23
Persevering in Complex Tasks	2B	10
Normalizing Mistakes	2B	8
Asking Higher Level Questions	3B	8

Research Question 3. The researcher used one-on-one interviews with administrators to answer the third research question: What are administrators' perceptions of the impact that lesson study has on their math teachers' professional growth as defined by the Danielson FFT classroom observation instrument? Table 29 shows the codes that are aligned to the Danielson FFT with the highest frequency in the data corpus.

According to administrators, teacher participation in lesson study has impacted their teachers' philosophy of how kids learn. Specifically, administrators indicated their teachers had shifted their math instruction towards a more student-centered approach. They believed their teachers have been more willing to take pedagogical risks as they move away from rote memorization and drill towards a more discovery-based instructional approach. As a result, they felt student engagement has increased as students at all levels are invited to share their thinking strategies and solutions This result provides evidence of professional growth in component 3C (Engaging Students in Learning) of the Danielson FFT (Danielson, 2007).

Secondly, administrators explained the move toward a more discovery-based approach to math has resulted in students buying in to the learning and even taking responsibility for the learning. As a result, the administrators believed their students are learning how to persevere in problem solving as they work through complex mathematical tasks. They believed the students are gaining confidence as they struggle to figure out solutions on their own. These results are connected to professional growth in component 2B (Establishing a Culture for Learning) of the Danielson FFT (Danielson, 2007).

Administrators noted an increase in the amount of mathematical discourse as their teachers have participated in lesson study. The administrators described math lessons where students learn through powerful mathematical discussions. In these discussions the students are critiquing one another's thinking and providing rebuttal arguments to mathematical ideas. In addition, the administrators indicated their math teachers are asking deeper questions. In these classrooms, the teachers don't provide all the answers but rely on high level questioning to push the learning to a higher level. This result is connected to teacher professional growth in component 3B (Using Question and Discussion Techniques) of the Danielson FFT (Danielson, 2007). Lastly, administrators indicated their teachers are more readily able to formatively assess their math students as the students have more opportunity to make their thinking visible. This result is correlated to professional growth in component 3D (Using Assessment in Instruction) of the Danielson FFT (Danielson, 2007).

Table 29

Highest Frequency Administrator Interview Codes

Pattern Code	Danielson Component	Frequency
Safe Learning Environment	2B	11
Student-Centered Learning	3C	10
Problem Based Learning	3C	10
Support of Productive Struggle	2B	7
Increased Student Explanations	3A	7
Increased Student Discourse	3B	7
Higher Level Questions	3B	6
Increased Evidence of Learning	3D	6

Conclusion

The purpose of this study was to investigate the impact of lesson study on the professional development of math teachers in Idaho. The researcher used the Danielson FFT observation instrument using an outside expert to collect quantitative data regarding participants' professional growth (Danielson, 2007). The researcher also conducted six focus group interviews with K-12 teachers to determine their perspectives of how lesson study has impacted student engagement in their classrooms. Focus groups were used to include as many teachers as possible in the qualitative portion of the study. The small number of administrator participants afforded the researcher the opportunity to conduct one-on-one interviews with administrators to obtain their perspectives of the impact on their teachers' professional growth as outlined by the Danielson FFT.

The researcher used the classroom observation instrument to collect quantitative data for two independent groups: (1) teachers who had engaged in lesson study for 0-2 years and (2) teachers who had engaged in lesson study for 3-6 years. The researcher used a Mann Whitney U test to analyze differences in scores between the two groups using the following components from Danielson FFT (see Appendix I):

- Establishing an Environment of Respect and Rapport (2A)
- Establishing a Culture for Learning (2B)
- Communicating with Students (3A)
- Using Question and Discussion Techniques (3B)
- Engaging Students in Learning (3C)
- Using Assessment in Instruction (3D)

The data did not show a statistically significant difference in scores of the two groups in components 2A, 2B, and 3A. However, the data did show a statistically significant difference in scores for components 3B, 3C, and 3D. Specifically, teachers who participated in lesson study longer had statistically significantly higher scores in the areas of using question and discussion techniques, engaging students in learning, and using assessment in instruction.

The researcher used the focus group data to determine how teachers feel lesson study has impacted student engagement during instruction. The results indicate the teachers felt lesson study had taught them how to create safe learning environments where students feel comfortable taking intellectual risks. As a result, they saw increased student engagement in mathematical discourse and the engagement of students in discovery learning as they persevere in solving complex mathematical tasks.

The researcher used the administrator interview data to determine administrator perceptions of how lesson study has impacted their math teacher's professional growth using the

Danielson FFT. The overarching theme is that administrators believed teachers have shifted toward a more student-centered approach to math instruction. As a result, the administrators see an improved culture for learning as teachers normalize mistakes as part of the learning process. They also believed their teachers have improved in their ability to ask higher-level questions that promote mathematical discourse. In addition, the administrators see their teachers engaging students more in the learning as they design lessons that allow students at all levels to discover their own learning as they work to solve context-based mathematical tasks. As a result, the administrators believed the teachers have increased their ability to collect evidence of student learning as students are spending more time explaining and justifying their thinking. The following chapter provides a discussion of these results.

Chapter V

Discussion

Introduction

The Common Core State Standards for Mathematics (CCSSM) were designed to raise the level of rigor of math education in the United States (Anderson-Pence, 2015; NCTM, 2014; NGA & CCSSO, 2010; Schmidt, 2012; Schoenfeld, 2004; Steffe, 2017). The CCSSM call for student-centered classrooms where students engage in discovery learning tasks on a regular basis (Jentsch & Schlesinger, 2017; NCTM, 2014; Takahashi & McDougal, 2016). This requires teachers to change their role from a transmitter of knowledge to a facilitator of learning (Anderson-Pence, 2015; Hattie et al., 2017; Herrera & Owens, 2001 Jentsch & Schlesinger, 2017; Schoenfeld, 2004; Takahashi & McDougal, 2016). Although the CCSSM define student outcomes for math, they do not define teacher actions for instruction (Kolb, 2015; NCTM, 2014).

Highly effective professional development programs can provide teachers with the necessary knowledge of content and pedagogy to implement state content standards (Alamri et al., 2018; Blank et al., 2007; Desimone, 2009; Guskey, 2000; Kruse et al., 2017; Sandholtz et al., 2016; Shriki & Patkin, 2016; Sztajn et al., 2012). Highly effective professional development is defined as being content-focused, sustained, job-embedded, collaborative, based on active learning, and includes expert support (Aykaç & Yildirim, 2017; Blank et al., 2007, 2010; Danielson & McGreal, 2000; Darling-Hammond et al., 2017; Hammer, 2013; McDonald, 2012; McElearney et al., 2019; Yoon et al., 2007). Lesson study is a model of highly effective professional development that originated in Japan and has become popular in the United States over the last two decades (Dudley et al., 2019; Godfrey et al., 2018; Lewis et al., 2006, 2019; Seleznyov, 2018; Thinwiangthong et al., 2020; Xu & Pedder, 2015). Lesson study is a collaborative, sustained, and job-embedded model of professional development where teachers work under the direction of a facilitator to research a topic, design and teach a lesson, and reflect on student learning (Druken, 2015; Lewis et al., 2006, 2019; Lomibao, 2016; Moghaddam et al., 2015; Takahashi & McDougal, 2016; Xu & Pedder, 2015).

Lesson study has become a growing model of professional development among Idaho math teachers since 2015 (R. Birnie, personal communication, April 22, 2020; R. Dent, personal communication, April 22, 2020). These professional development efforts have been funded by the Idaho Math Initiative (IMI). The IMI authorized the Idaho State Department of Education (ISDE) to provide high-quality professional development to Idaho math teachers (Idaho Math Initiative of 2014). The literature acknowledges the importance of communicating the outcomes of such programs to stakeholders (Alamri et al., 2018; Bill and Melinda Gates Foundation, 2013; Garcia et al., 2013; Godfrey et al., 2018; Guskey, 2000). However, there is currently no empirical research investigating the professional growth of Idaho math teachers from lesson study programs. The purpose of this study was to investigate the impact of lesson study programs on the professional growth of Idaho math teachers. The researcher used the Danielson Framework for Teaching (FFT) as the framework to define and measure professional growth (Danielson, 2007).

Discussion of Results

The researcher triangulated the quantitative and qualitative data to identify overarching themes of how lesson study has impacted the professional growth of Idaho math teachers. Triangulation is the process of corroborating evidence from different methods of data collection and has been shown to increase the validity of the findings (Creswell & Guetterman, 2019; Lincoln & Guba, 1985). The quantitative data was segregated into two groups based on the number of years the participants had participated in the lesson study program. This was done to compare the Danielson classroom observation data to investigate whether those who had more experience with lesson study scored higher on the instrument. The qualitative data was not segregated by number of years' experience with lesson study. This was done to include as many teachers as possible to answer the second research question regarding teacher perceptions of the impact of lesson study on student engagement. The administrator interview data provided insight into the third research question regarding the impact of lesson study on teacher professional growth. Table 30 shows which instruments provided evidence of teacher professional growth for each component of the Danielson FFT analyzed The following sections discuss the results for each component.

Table 30

Areas of Professional Growth by Instrument

Danielson Component	Observation Instrument	Teacher Focus Group Interviews	Administrator Interviews
Establishing an Environment of Respect and Rapport (2A)		X	X
Establishing a Culture for Learning (2B)		X	X
Communicating with Students (3A)		X	X
Using Question and Discussion Techniques (3B)	X	X	X
Engaging Students in Learning (3C)	X	X	X
Using Assessment in Instruction (3D)	X	X	X

Note. This table shows which instruments showed teacher professional growth in each Danielson component.

Establishing an Environment of Respect and Rapport

Component 2A of the Danielson framework is designed to measure the level of respect and rapport in the classroom (Danielson, 2007). The rubric for this component describes a distinguished classroom as one with highly respectful social interactions and one where students contribute to high levels of civility (see Appendix I). Interactions should be respectful and inviting so that students feel comfortable taking intellectual risks (Hattie et al., 2017; Schoenfeld, 2020; Thinwiangthong et al., 2020).

The qualitative data from this study indicated teachers and administrators felt lesson study helped teachers create safe learning environments where students take intellectual risks.

However, the quantitative data did not show a statistically significant difference in scores in this component between teachers with 0-2 years and teachers with 3-6 years' experience with lesson study. One possible explanation for the discrepancy is that this component of the framework assumes students will be comfortable taking intellectual risks because of respectful relationships. However, participants of this study perceived students felt comfortable taking intellectual risks because mistakes had been normalized as part of the learning process. Therefore, it is possible that teachers were able to establish respectful relationships with students regardless of their experience with lesson study. However, the qualitative data suggested teachers who participate in lesson study believed they have created safe learning environments where students can take intellectual risks.

Establishing a Culture for Learning

Component 2B of the Danielson framework is designed to measure the culture for learning in the classroom (Danielson, 2007). The rubric for this component describes the distinguished classroom as one where students understand their role as learners, consistently expend effort to learn, and the students themselves assume the responsibility for high quality work (see Appendix I).

Participants in this study believed that teachers' experiences with lesson study led to improved learning cultures during math lessons. Specifically, teachers and administrators felt the students of lesson study participants had assumed ownership of the learning and were expending effort to learn by persevering in mathematical problem solving. It was surprising that the quantitative data did not show a statistically significant difference in scores between groups in this component since an improvement in learning culture was a major theme in the qualitative data. One possible explanation for the discrepancy is the difference between how high-quality learning culture is defined for math classrooms by the NCTM and how it is defined in the Danielson framework. The NCTM defines high-quality learning cultures as those where students strive to continuously improve and are trained to persevere in problem solving (NCTM, 2014; Strom et al., 2018). The qualitative data in this study provided evidence that teachers perceived an improvement in their learning cultures in this regard. Specifically, participants felt their students had learned how to persevere in problem solving as they work through complex mathematical tasks. Although the Danielson classroom observation instrument includes this description, it also requires evidence students are responsible for making revisions and assisting their peers in the use of language (see Appendix I). Therefore, it is possible teachers were able to establish effective learning cultures as defined by the Danielson framework regardless of their experience with lesson study. However, participants believed lesson study helps teachers grow professionally by helping them develop high-quality learning cultures as defined by the NCTM where students persevere in problem solving.

Communicating with Students

Component 3A of the Danielson framework describes ways distinguished teachers communicate with their students (Danielson 2007). The rubric includes such things as communicating learning objectives, communicating instructions, and explaining content (see Appendix I). Embedded in this component is the expectation that distinguished teachers provide opportunities for students to explain content to their classmates. Participants in this study described math lessons where students had increased opportunities to explain mathematical content to each other. Specifically, the participants mentioned the students were explaining their strategies, their solutions, and their mathematical reasoning as they worked collaboratively to solve problems.

However, the participants had not perceived any impact of lesson study on the other elements of this component such as communicating objectives or instructions. Specifically, administrators provided no evidence that teachers' experience with lesson study had impacted their ability to explain mathematical content to students. Therefore, it was not surprising that the quantitative data from the classroom observation instrument did not show a statistically significant difference between the groups in this component. It is possible that teachers were able to demonstrate effective communication with students regardless of their experience with lesson study. However, teachers and administrators perceived that lesson study participants provided more opportunities for students to explain mathematical content to each other.

Using Question and Discussion Techniques

Component 3B of the Danielson framework describes effective ways for teachers to use question and discussion techniques (Danielson, 2007). The rubric describes a distinguished classroom as one where teachers ask questions to challenge student thinking and one where students engage in discourse (see Appendix I). This component is based on the theory that social interaction plays a critical role in cognitive development (Hattie et al., 2017; Lutz & Huitt, 2004; Powell & Kalina, 2009). Social constructivist theory suggests students construct their learning through language as they articulate their thoughts and clarify their arguments (Powell & Kalina, 2009).

Qualitative data suggested lesson study had positively impacted teacher professional growth in this component. Teachers and administrators perceived lesson study participants asked deeper questions to push learning to a higher level. In addition, teacher participants believed these higher-level questions enabled them to create student-led discussions. As a result, they perceived their students had become more comfortable explaining their mathematical thinking to their classmates. The quantitative data corroborated this finding as teachers who had participated in lesson study longer had statistically significant higher mean rank scores in question and discussion techniques than teachers with less experience with lesson study.

One possible explanation for why both the qualitative and quantitative data shared this finding is that fact that the Danielson framework and the NCTM standards are closely aligned in their descriptions of high-quality question and discussion techniques. The NCTM describes a high-quality math classroom as one where student discourse is initiated, students carry the conversation themselves, and students defend and justify their thinking (NCTM, 2014; Strom et al., 2018). This is much like the description in the Danielson framework that describes high-quality teachers as those who use questions to promote and challenge student thinking (Danielson, 2007). Therefore, it is theorized that teachers who had engaged in lesson study longer scored higher on the Danielson classroom observation instrument in this component as they learned to create mathematical discourse according to the standards outlined by the NCTM.

Engaging Students in Learning

Component 3C of the Danielson framework describes how high-quality teachers engage students in the learning (Danielson, 2007). The rubric for this component describes the distinguished classroom as one where students are intellectually engaged in activities that require complex thinking. In addition, students may initiate inquiry and serve as resources for one another (see Appendix I). This description is based on constructivist learning theory that suggests learning occurs when students construct knowledge for themselves (Lutz & Huitt, 2004). Constructivist math instruction will contain opportunities for students to be actively involved in solving problems that are situated in real-world contexts (Caprioara & Anghelide, 2016; Hattie et al., 2017; Ultanir, 2012).

Qualitative data suggested lesson study participants had grown professionally in their ability to engage students in the learning. Teachers and administrators felt that lesson study participants had shifted their instruction to a more student-centered, discovery-learning approach. Specifically, participants felt their math instruction had become centered around complex, real-world tasks where the students discovered mathematical processes. Since the students were free to attack the problems from all different angles, the participants perceived even the lowest performing students had an entry point to the assignments. The result was they felt an increased level of student engagement for more students. The quantitative data supported this finding as teachers who had participated in lesson study longer had statistically significant higher mean rank scores for engaging students in learning.

One possible explanation why the classroom observation instrument supported the qualitative findings is that component 3C of the Danielson framework is aligned to the NCTM teaching standards. According to the NCTM, math teachers are expected to facilitate tasks that promote reasoning and problem solving (Caprioara & Anghelide, 2016; NCTM, 2014). Teachers can facilitate deep learning with tasks that are open-ended and have multiple strategies or multiple solutions (Schoenfeld, 2020). This is very similar to the description in the classroom observation instrument that requires evidence of students being intellectually engaged in complex thinking (see Appendix I). Therefore, it is theorized that teachers who had engaged in lesson study longer scored higher on the Danielson classroom observation instrument in this component as they learned to engage students in discovery learning as outlined by the NCTM teaching standards.

Using Assessment in Instruction

Component 3D of the Danielson framework describes how teachers are to use assessment during instruction (Danielson, 2007). The rubric for this component describes the distinguished classroom as one where assessment is fully integrated into instruction, students have contributed to the success criteria, there are a variety of forms of feedback, and students self-assess and monitor their own progress (see Appendix I).

Qualitative data revealed that participants believed the shift towards a more constructivist approach to math instruction allowed teachers to collect more evidence of student learning as students were given more opportunities to explain their thinking. Quantitative data from the classroom observation instrument corroborated this finding as teachers who had participated in lesson study longer had statistically significant higher mean rank scores in using assessment in instruction. The NCTM also describes high-quality teachers as those who use assessment as an ongoing process to inform instruction (NCTM, 2014). Therefore, it is theorized that teachers who had engaged in lesson study longer scored higher on the Danielson classroom observation instrument in this component as they learned to collect formative evidence of student learning according to the NCTM standards (NCTM, 2014; Strom et al., 2018).

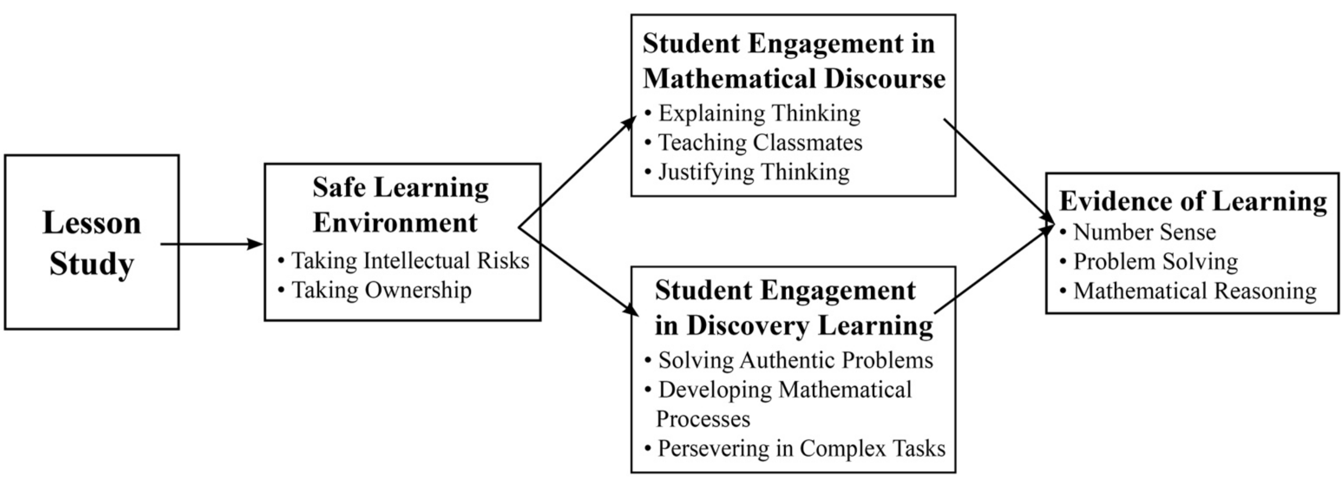
Although formative assessment and feedback is important to good teaching, in high-quality programs, students learn to assess their learning relative to the success criteria and recognize the quality of their own work (Danielson, 2007; Hattie et al., 2017; NCTM, 2014; Thinwiangthong et al., 2020). However, this study did not find any evidence that lesson study participants had grown professionally by providing opportunities for students to monitor their own learning. Although participants indicated students had taken an increased role in the learning, they felt lesson study had no impact on student self-assessment in their classrooms.

Impact of Lesson Study on Teacher Professional Development

Results showed teachers and administrators perceived lesson study facilitated the creation of safe learning environments where students take intellectual risks. As a result, teachers and administers believed students are more engaged in mathematical discourse. This finding is supported by the fact that teachers who had engaged in lesson study longer had higher mean rank scores in question and discussion techniques. Teachers and administrators also perceived that students whose teachers engaged in lesson study were taking ownership of the learning. As a result, they believed students were spending more time engaged in discovering their own learning through authentic mathematical problems. This is support by the fact that teachers who engaged in lesson study longer had higher mean rank scores in engaging students in learning. Teachers and administrators believed that the increase in mathematical discourse and discovery learning activities provided teachers more evidence of student learning during instruction. This is supported by the fact that teachers who engaged in lesson study longer had higher mean rank scores in using assessment in instruction. Figure 14 provides a summary of these findings.

Figure 14

Model of Teacher Professional Growth from Lesson Study



Note. This diagram provides a summary of the findings regarding the impact of lesson study on teacher professional growth.

Significance of the Findings

Current standards of math education in the United States call for student-centered classrooms where all students learn by productively struggling with complex mathematical tasks and are challenged to explain and justify their thinking (Jentsch & Schlesinger, 2017; NCTM, 2014; Takahashi & McDougal, 2016). These standards are based on constructivist principles of learning and require teachers to act as facilitators of discovery learning activities (Anderson-Pence, 2015; Hattie et al., 2017; Herrera & Owens, 2001; Jentsch & Schlesinger, 2017; Schoenfeld, 2004; Takahashi & McDougal; 2016). This study adds to the research by measuring teacher perceptions of a lesson study program using a framework for teaching aligned to constructivist-based, student-centered teaching (Danielson, 2007)

The literature acknowledges lesson study can increase teachers' confidence in discovery, problem-solving approaches to learning (Cajkler et al., 2015; Dudley et al., 2019; Helmbold et al., 2021; Lewis et al., 2019). The results of this study are consistent with this research as the results indicated a shift of participants' philosophy towards a more student-led model of instruction. As one teacher said, "They're coming up with those things and [it] is much more student directed." This study contributes to the research by adding the perspectives of administrators. Administrators in this study provided evidence that their teachers have changed their philosophy of how kids learn to a more student-centered approach.

The NCTM describes high-quality classrooms as those where problem solving is more about developing mathematical practices of mind, rather than getting the right answer (Schoenfeld, 2020). The results of this study added the perceptions of administrators who believed that teachers had shifted the focus of their instruction to mathematical processes rather than answer-finding. This study adds the unique finding that by normalizing mistakes teachers created safe learning environments. Participants in this study described classrooms where students felt comfortable taking intellectual risks as they became comfortable with failure as part of the learning process.

High-quality math instruction includes purposeful questions and requires students to reflect on their answers and those of their classmates (Anderson-Pence, 2015; Hattie et al., 2017; NCTM, 2014; Schoenfeld, 2020; Strom et al., 2018;). This is based on social constructivist learning theory that purports knowledge is constructed by the learner through social interactions (Bates, 2019; Lutz & Huitt, 2004; Matthews, 2003; Powell & Kalina, 2009; Steffe, 2017. The literature provides evidence that lesson study can increase teachers' capacity to orchestrate discussions by asking focused questions and inviting students to explain and justify their thinking (Thinwiangthong et al., 2020; Widjaja et al., 2015). The results of this study found lesson study participants believed the mathematical discourse in their classrooms had increased by asking higher-level questions and teaching their students how to critique the thinking of their classmates. As one participant said, "[It's] a lot more social, it's more of a collaborative math experience." However, much of the previous lesson study research is based on teacher questionnaires and interviews (Cajkler et al., 2015; Dudley et al., 2019; Moghaddam et al., 2015; Murphy et al., 2017; Schipper et al., 2018; Thinwaingthong et al., 2020; Widjaja et al., 2015). The findings of this study are significant because they add quantitative evidence that teachers who engage in lesson study longer have higher mean rank scores in classroom discussion techniques as measured by a classroom observation instrument.

Students in high-quality classrooms strive to continuously improve and are trained to persevere in problem solving (Anderson-Pence, 2015; Hattie et al., 2017; NCTM, 2014; Schoenfeld, 2020; Strom et al., 2018). This is based on constructivist theory of learning, which suggests math students will construct meaning through the process of tackling complex problems and applying their knowledge to authentic situations (Caprioara & Anghelide, 2016; Hattie et al., 2017; Ultanir, 2012). Previous studies have found that teachers' involvement with lesson study can lead to increased student engagement in problem-solving approaches to math (Helmbold et al., 2021; Lewis et al., 2019; Moghaddam et al., 2015). These studies are based on teachers' perceptions of the impact of lesson study on their practice. The findings of this study are significant because they add quantitative evidence that teachers who engage in lesson study longer have higher mean rank scores in student engagement as measured by a classroom observation instrument.

High-quality teachers use assessment as an ongoing process to inform instruction, adjusting as necessary (NCTM, 2014; Thinwiangthong et al., 2020). Lesson study has also been shown to provide opportunities for teachers to focus on student thinking in the classroom environment (Amador & Carter, 2018; Celik & Guzel, 2020; Dudley et al., 2019; Lewis et al., 2006; Pehlivan & Güzel, 2020; Widjaja et al., 2015). This provides an increased ability for teachers to formatively assess student thinking and progress towards the learning target (Thinwiangthong et al., 2020). This study had similar results. Teacher participants in this study indicated teachers were more readily able to see where students are at individually and identify next steps in the learning. The findings of this study are significant as they provide quantitative evidence that teachers who engage in lesson study longer have higher mean rank scores in using assessment during instruction as measured by a classroom observation instrument.

Limitations of the Study

It is important to identify the limitations and weaknesses that are present in a study to inform future research on the subject (Creswell & Guetterman, 2019). Chapter 3 presented limitations known to the researcher at the outset of the study. This section presents additional limitations that resulted from sampling constraints that arose during the study. Sampling can create limitations on the generalizability of a study (Colorafi & Evans, 2016).

This study was limited to four schools in one region of North-Central Idaho. Three elementary schools and three secondary schools in the region were invited to participate. Of those schools invited, three elementary and one secondary school agreed to participate. As a result, secondary teachers were underrepresented in the sample population. This limits the generalizability of the results to secondary education.

The researcher for this study selected participants based on the number of years they had participated in lesson study. Lesson study in this region began six years ago with only a few teachers volunteering to participate. As a result, there were not many participants available who had engaged with lesson study for the full six years. Since that time, lesson study has become a school-wide program in all four participating schools. Therefore, there were more teachers available to participate who had engaged in lesson study for 0-2 years. This created an imbalance in the independent samples for the quantitative analysis.

The researcher collected quantitative data by video-recording math lessons of participating teachers. The researcher analyzed quantitative data by comparing the Danielson FFT scores between teachers who had participated in a lesson study program for 0-2 years to those who had participated 3-6 years. However, the researcher found it difficult to get teachers to agree to be video recorded. Teachers who had not participated in lesson study were the most reluctant to participate. This created a limitation in the number of sample lessons from teachers who had not participated in lesson study. The overall result was a small sample size ($N = 18$). Due to the small sample size, the quantitative results of this study were based on a non-parametric test. Consequently, the statistically significant findings were based on differences in mean rank scores as opposed to mean scores.

The researcher found many teachers eager to discuss their experiences with lesson study for the qualitative portion of the study. However, when studying teachers and their practice, one is most likely to develop relationships with exemplary teachers who are eager to discuss their teaching practices. Less proficient teachers may be reluctant about sharing inadequacies (Maxwell, 2013). This suggests teachers who did not have positive experiences with lesson study may have been underrepresented in the sample population. In addition, the qualitative description method used in this study is best used to obtain a description of a phenomenon. However, its' findings may be less generalizable due to its low-inference nature (Neergaard et al., 2009).

Lastly, many participants credited the success of the lesson study program to the strength of the regional facilitator. Administrators and teachers alike described a very knowledgeable facilitator who spent many hours researching topics for the teachers to study. Therefore, the results of this study may not be generalizable to a lesson study program without such a dedicated facilitator.

Recommendations for Further Research

This study addressed an existing gap in the literature regarding the impact of lesson study on the professional growth of math teachers. The results of this study indicated teachers who had more experience with lesson study had higher mean rank scores in the areas of question and discussion techniques, student engagement, and using assessment during instruction as measured by the Danielson FFT classroom observation instrument. However, further researcher is needed to investigate the strength of the relationship and the generalizability of the results. In particular, further research is needed to investigate the impact of lesson study on secondary math teachers' professional growth.

This study was limited to Region II in Idaho, which has used lesson study as a model of professional development for six years. Lesson study has also been used in Region IV in Idaho during the same time period. The participants in Region IV use a slightly different model of lesson study where the research lesson is retaught. Further research could compare the impact of the two models of lesson study between the two regions.

This study demonstrated growth of Idaho math teachers using the Danielson FFT. Further researcher could compare the professional growth of Idaho math teachers in other regions of Idaho that use other models of professional development such as conferences, workshops, and video-coaching. The results could be compared to determine which model has the greatest impact on professional growth using the Danielson FFT.

The regional math center housed at a higher education institution in Northern Idaho facilitated the lesson study program investigated in this study. This math center used a curriculum based on discovery-learning instruction for its lesson study program. Further research could investigate the impact of lesson study in other areas where a different curriculum is used. This would contribute to the generalizability of the findings.

Teacher participants in this study provided evidence they have transferred the teaching practices they have learned during lesson study to other content areas. This was particularly true in question and discussion techniques. Therefore, researchers could investigate the impact of lesson study on teacher professional growth in content areas besides math, such as English and science.

Lastly, further research could study the impact of lesson study on the achievement of Idaho math students. A longitudinal study could include the correlations between the involvement of schools in lesson study and the achievement of students on standardized tests. Research of this type would most likely investigate the growth of student achievement over time. The research suggests that the most successful changes in instruction occur because of continuous improvement on the part of teachers and administrators through sustained effort. Therefore, it may not be possible to measure continuous student improvement within a single year using quantitative standardized test data (Godfrey et al., 2018; Guskey, 2000).

Implications for Professional Practice

The first implication for professional practice it that lesson study could be used as an effective model of professional development for math teachers. Specifically, lesson study can be used as a method to change teacher practice to be more in line with the NCTM teaching standards. The NCTM defined high-quality math teachers as those who:

- establish mathematics goals to focus learning,
- implement tasks that promote reasoning and problem solving,
- use and connect mathematical representations,
- facilitate meaningful mathematical discourse,
- pose purposeful questions,
- build procedural fluency from conceptual understanding,
- support productive struggle, and
- elicit and use evidence of student thinking (NCTM, 2014).

Teachers in this study demonstrated growth in all these areas except for establishing mathematics goals and building procedural fluency. Therefore, facilitators of lesson study programs could enhance their practice by adding opportunities for teachers to practice establishing goals for learning in addition to helping teachers design learning activities that develop fluency.

In March 2022, the Idaho legislature voted to replace the CCSSM with new Idaho math content standards. The new standards are based on the CCSSM, which include critical thinking through authentic problem solving. However, the new standards add new requirements for the mastery of mathematical facts. The new standards have been reworded to reduce the complexity of the verbiage and some standards have been prioritized. Learning progressions have been developed with the consideration of age appropriateness of the concepts, particularly in the younger grades. Lastly, the new standards include a description of what the SMPs should look like at each grade level (Idaho State Department of Education, 2022). The results of this study suggest lesson study could be used as a model of professional development to support teachers' implementation of the new standards. Specifically, the addition of mastery standards could provide teachers an opportunity to practice designing a balance between discovery learning and fluency building exercises during lesson study sessions.

Implications for Policy

This study focused on the impact of a lesson study program on the professional growth of math teachers in Idaho. Professional growth was measured using the Danielson FFT, which is used throughout Idaho as a framework for good teaching. The results of the study suggest lesson study had a positive impact on the professional growth of Idaho math teachers, particularly in the areas of student engagement and student discourse. These results can inform state and local agencies regarding the expenditures on teacher professional development efforts moving forward.

The goal of any education program is to support the academic achievement of its students. The results of this study regarding the impact of lesson study on the achievement of Idaho students on standardized tests were mixed. This is consistent with previous research

(Godfrey et al., 2018; Lewis & Perry, 2017; Murphy et al., 2017). This may be because teachers are expected to teach mathematical reasoning and perseverance in problem solving, while standardized assessments are norm-referenced, multiple choice tests (Hattie et al., 2017). These assessments may not be suited to measure more complex forms of learning such as critical thinking and problem solving that are required by the current standards (Danielson & McGreal, 2000; Lynch et al., 2017). The participants in this study expressed frustration at the lack of alignment between expected instructional practice and standardized tests. Many felt they had improved their practice as defined by the Danielson FFT but hadn't seen the change reflected in standardized test scores. The participants explained they were confused by these results and the progress they thought they were making with their students. The Idaho State Department of Education will be conducting a study during the 2022-23 school year to investigate the alignment of the state standardized test with the new state math standards. This is an opportunity for policymakers to implement policy regarding state assessments based on the findings of the alignment study. In an era of high teacher turnover, policymakers cannot afford to send mixed messages to math teachers. The results of this study implied lesson study can be effective in aligning teacher practice to intended outcomes – educational leaders just need to communicate a clear message to teachers of what those need to be.

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Appendix A

Site Permission Letters

[redacted]

May 10, 2021

Northwest Nazarene University
Attention: HRRC Committee
Helstrom Business Center 1st Floor
623 South University Boulevard
Nampa, ID 83686

RE: Research Proposal Site Access for Mrs. Sheree L. Keller

Dear HRRC Members:

This letter is to inform the HRRC that the Administration at [redacted] has reviewed the proposed dissertation research plan including subjects, assessment procedures, proposed data collection procedures, data analysis, and purpose of the study. Mrs. Keller has permission to conduct her research study in the district of and with the students and staff of the [redacted]. The authorization dates for this research are July 2021 to April 2022.

[redacted]

Superintendent

April 28, 2021

Northwest Nazarene University
Attention: HRRC Committee
Helstrom Business Center 1st Floor
623 South University Boulevard
Nampa, ID 83686

RE: Research Proposal Site Access for Mrs. Sheree L. Keller

Dear HRRC Members:

This letter is to inform the HRRC that the Administration at [redacted] has reviewed the proposed dissertation research plan including subjects, assessment procedures, proposed data collection procedures, data analysis, and purpose of the study. Mrs. Keller has permission to conduct her research study in the district of and with the students and staff of the [redacted]. The authorization dates for this research are July 2021 to April 2022.

Respectfully,

[redacted]

Appendix B

Invitation Email for Classroom Observation

Hello,

I am conducting research into the impact that lesson study is having on the professional growth of math teachers in Idaho. The objective of the study is to look for trends in growth among lesson study participants using the Danielson Framework for Teaching. You are being invited to participate in the study because of your involvement in lesson study.

If you agree to participate, you will be invited to allow a researcher to video-record a math lesson for approximately 15 minutes. A certified Danielson practitioner will evaluate the video. All information is completely confidential, which means no one except the researcher will be able to connect any data collected to you personally. You will receive a $10 gift certificate to Amazon as a thank you for your participation in the study.

Your participation will make a big difference! The information we obtain will help inform the professional development opportunities for Idaho math teachers moving forward.

If you have questions or concerns, please contact Sheree Keller by replying to this email. If you require additional assistance, please contact my research supervisor at DLSlemmer@nnu.edu.

Thank you so much for participating!

Sheree Keller
Northwest Nazarene University
slkeller@nnu.edu

Appendix C

Informed Consent Form—Classroom Observation

A. PURPOSE AND BACKGROUND

My name is Sheree Keller, and I am a graduate student at Northwest Nazarene University. I am inviting you to participate in a research study. Involvement in the study is voluntary. I am interested in learning more about teachers' experiences with math professional development. I am particularly interested in how lesson study impacts teachers' professional growth.

B. PROCEDURES
If you agree to be in the study, the following will occur:

1. You will be asked to sign an Informed Consent Form, volunteering to participate in the study.
2. The primary researcher will observe you teach a math lesson for about 15 minutes. The researcher will video record the lesson.
3. You will be asked to read a debriefing statement at the conclusion of the observation.

C. RISKS/DISCOMFORTS
The follow are potential risks:

1. It may make you uncomfortable to have a researcher in your classroom, but you are free to stop participation at any time.
2. Any data collected during the observation will remain confidential. This means I will assign a number to your observation, and only I will have the key to indicate which number belongs to which participant.
3. All data from notes and digital recordings will be kept in a secure, password-protected folder on the principal investigator's personal computer. In compliance with the Federal wide Assurance Code, data from this study will be kept for three years, after which all data from the study will be destroyed (45 CFR 46.117).
4. Only the primary researcher and the research supervisor will be privy to data from this study. As researchers, both parties are bound to keep data as secure and confidential as possible.

D. BENEFITS
This research will help us understand professional development outcomes for math teachers in Idaho.

E. PAYMENTS
You will receive a $20 gift card to Amazon as a thank you for participating.

F. QUESTIONS
If you have questions or concerns about participation in this study, you should first talk with the investigator. Sheree Keller can be contacted via email at slkeller@nnu.edu, via telephone at 208-794-5501 or by writing: Sheree Keller, 450 W. Island Ct., Nampa, ID 83686. You may also discuss questions or concerns with the research supervisor. Dr. Duane Slemmer can be contacted via email at dlslemmer@nnu.edu, or via telephone at 208-467-8039.

Should you feel distressed due to participation in this, you should contact your own health care provider.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on your present or future status as a professional.

I give my consent to participate in this study:

____ __________________

Signature of Study Participant **Date**

I give my consent for the lesson to be video recorded in this study:

____ __________________

Signature of Study Participant **Date**

____ __________________

Signature of Person Obtaining Consent **Date**

THE NORTHWEST NAZARENE UNIVERSITY INSTITUTIONAL REVIEW BOARD HAS REVIEWED THIS PROJECT FOR THE PROTECTION OF HUMAN PARTICIPANTS IN RESEARCH.

Appendix D

Invitation Email for Focus Group

Hello,

I am conducting research into the effectiveness of lesson study as a form of professional development for math teachers. The purpose of the study is to investigate the impact lesson study has on the professional growth of math teachers in Idaho.

You are being invited to participate in a focus group interview regarding your experiences with lesson study. The interview questions will be regarding your perceptions of how lesson study has impacted your students' role in math instruction. The interview transcript will be completely confidential, which means no one except the researcher will be able to connect any of the responses to you personally. You will receive a $20 gift certificate to Amazon as a thank you for your participation in the study.

Your participation is important! The information we obtain will help inform the professional development opportunities for Idaho math teachers moving forward.

If you have questions or concerns, please contact Sheree Keller by replying to this email. If you require additional assistance, please contact my research supervisor at DLSlemmer@nnu.edu.

Thank you so much for participating!

Sheree Keller
Northwest Nazarene University
slkeller@nnu.edu

Appendix E

Focus Group Interview Protocol

Thank you once again for your willingness to participate in the focus group portion of my study. As I mentioned before, my study seeks to understand how your participation in lesson study has impacted your math students' participation in learning. Our interview today will last approximately one hour during which time I will ask you questions related to your experiences with lesson study.

Prior to the interview you completed a consent form indicating that I have your permission to audio record our conversation. Are you still ok with me recording our interview?

If yes: Thank you! Please let know if at any point you want me to turn off the recorder or keep something you said off the record.

If no: Thank you for letting me know. I will only take notes during our conversation.

Before we begin the interview, do you have any questions?
Feel free to ask if any questions that arise at any point in the study. I would be happy to discuss them at any point.

Introductory Questions:

- What is your name?
- What grade(s) do you teach?
- How long have you been teaching?
- How did you get involved in lesson study?
- How long have you participated in lesson study?

Transition Questions:

- In general, how has your participation in lesson study affected the learning culture of your MATH classrooms?

Key Questions:

- How has your participation in lesson study affected the mathematical discourse (explain what this means) in your classroom?
- How has your participation in lesson study affected your students' ability to explain mathematical content?
- How has your participation in lesson study affected your students' engagement (explain what this means) in the learning?

- How has your participation in lesson study affected YOUR ability to assess and monitor your student's growth?
- How has your participation in lesson study affected your STUDENT'S ability to self-assess and monitor their own progress?
- In general, how do you feel your participation in lesson study has impacted your students' achievement in math?

Closing Questions:

- Before we conclude the interview, is there anything about your experiences with lesson study we haven't had the chance to discuss?
- Is there anything else you would like to share or would be helpful for me to know?

Thank you so much for your participation today! This information will help us better understand the professional needs of math teachers in Idaho. I will follow up via email summarizing our discussion today. You will have an opportunity to verify that the interview summary accurately represents your views.

Appendix F

Informed Consent Form—Focus Group

A. PURPOSE AND BACKGROUND

My name is Sheree Keller, and I am a graduate student at Northwest Nazarene University. I am inviting you to participate in a research study. I am interested in learning more about teachers' experiences with lesson study. I am particularly interested in how lesson study impacts teachers' professional growth as measured by the Danielson Framework for Teaching. If you agree to participate, you will be invited to a focus group interview regarding your experiences with lesson study. This will take approximately 60 minutes of your time.

B. PROCEDURES

If you agree to be in the study, the following will occur:

1. You will be asked to sign an Informed Consent Form, volunteering to participate in the study.
2. You will participate in a focus group interview. The questions will be regarding your perceptions of how participation in lesson study has impacted your experience with the Danielson Framework for Teaching.
3. You will be asked to read a debriefing statement at the conclusion of the observation.
4. You will receive an email from the researcher asking you to verify that the data accurately represents your views.

C. RISKS/DISCOMFORTS

1. The risk to you for participating in this study is the potential for discomfort when discussing your experience with lesson study and/or your experience with the Danielson Framework for Teaching. These risks will be minimized by letting you determine how much, if any, information you are willing to share. If you do not wish to continue, you have the right to withdraw from the study, without penalty, at any time.
2. Your responses will remain confidential. This means I will assign a number to your responses, and only I will have the key to indicate which number belongs to which participant. In any articles I write or any presentations that I make, I will use a pseudonym for you.
3. All data from notes and digital recordings will be kept in a secure, password-protected folder on the principal investigator's personal computer. In compliance with the Federal wide Assurance Code, data from this study will be kept for three years, after which all data from the study will be destroyed (45 CFR 46.117).
4. Only the primary researcher and the research supervisor will be privy to data from this study. As researchers, both parties are bound to keep data as secure and confidential as possible.

D. BENEFITS

The benefit of this research is that you will be helping us to understand how lesson study impacts teacher practice. This information should help us to align professional development programs with the needs of math teachers in Idaho.

E. PAYMENTS

You will receive a $30 gift card to Amazon as a thank you for participating.

F. QUESTIONS

If you have questions or concerns about participation in this study, you should first talk with the investigator. Sheree Keller can be contacted via email at slkeller@nnu.edu, via telephone at 208-794-5501 or by writing: Sheree Keller, 450 W. Island Ct., Nampa, ID 83686. You may also discuss questions or concerns with the research supervisor. Dr. Duane Slemmer can be contacted via email at dlslemmer@nnu.edu, or via telephone at 208-467-8039. Should you feel distressed due to participation in this, you should contact your own health care provider.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on your present or future status as a professional.

I give my consent to participate in this study:

____ ________________

Signature of Study Participant **Date**

I give my consent for the interview and discussion to be audio recorded in this study:

____ ________________

Signature of Study Participant **Date**

I give my consent for direct quotes to be used in this study:

____ ________________

Signature of Study Participant **Date**

____ ________________

Signature of Person Obtaining Consent **Date**

THE NORTHWEST NAZARENE UNIVERSITY INSTITUTIONAL REVIEW BOARD HAS REVIEWED THIS PROJECT FOR THE PROTECTION OF HUMAN PARTICIPANTS IN RESEARCH.

Appendix G

Invitation Email for Administrator Interview

Hello,

I am conducting research into the effectiveness of lesson study as a form of professional development for math teachers. The purpose of the study is to investigate the impact lesson study has on the professional growth of math teachers in Idaho.

You are being invited to participate in a one-on-one interview with the researcher. The interview questions will be regarding your perception of how lesson study has impacted the professional growth of math teachers on your staff. The interview transcript will be completely confidential which means no one except the researcher will be able to connect any of the responses to you personally. You will receive $20 gift certificate to Amazon as a thank you for your participation in the study.

Your participation is important! The information we obtain will help inform the professional development opportunities for Idaho math teachers moving forward.

If you have questions or concerns, please contact Sheree Keller by replying to this email. If you require additional assistance, please contact my research supervisor at DLSlemmer@nnu.edu.

Thank you so much for participating!

Sheree Keller
Northwest Nazarene University
slkeller@nnu.edu

Appendix H

Informed Consent Form—Administrator Interview

A. PURPOSE AND BACKGROUND

My name is Sheree Keller, and I am a graduate student at Northwest Nazarene University. I am inviting you to participate in a research study. I am interested in learning more about teachers' experiences with lesson study. I am particularly interested in how lesson study impacts teachers' professional growth as measured by the Danielson Framework for Teaching. If you agree to participate, you will be invited to participate in a one-on-one interview regarding your perceptions of how lesson study has impacted the professional growth of your math teachers. This will take approximately 30 minutes of your time.

B. PROCEDURES

If you agree to be in the study, the following will occur:

1. You will be asked to sign an Informed Consent Form, volunteering to participate in the study.
2. You will participate in a one-on-one interview. The questions will be regarding your perceptions of how lesson study has impacted the professional growth of the math teachers on your staff.
3. You will be asked to read a debriefing statement at the conclusion of the observation.
4. You will receive an email from the researcher asking you to verify that the data accurately represents your views.

C. RISKS/DISCOMFORTS

1. The risk to you for participating in this study is the potential for discomfort when discussing your experience with lesson study and its impact on your staff. These risks will be minimized by letting you determine how much, if any, information you are willing to share. If you do not wish to continue, you have the right to withdraw from the study, without penalty, at any time.
2. Your responses will remain confidential. This means I will assign a number to your responses, and only I will have the key to indicate which number belongs to which participant. In any articles I write or any presentations that I make, I will use a pseudonym for you.
3. All data from notes and digital recordings will be kept in a secure, password-protected folder on the principal investigator's personal computer. In compliance with the Federal wide Assurance Code, data from this study will be kept for three years, after which all data from the study will be destroyed (45 CFR 46.117).
4. Only the primary researcher and the research supervisor will be privy to data from this study. As researchers, both parties are bound to keep data as secure and confidential as possible.

D. BENEFITS

The benefit of this research is that you will be helping us to understand how lesson study impacts teacher professional growth. This information should help us to align professional development programs with the needs of math teachers in Idaho.

E. PAYMENTS

You will receive a $20 gift card to Amazon as a thank you for participating.

F. QUESTIONS

If you have questions or concerns about participation in this study, you should first talk with the investigator. Sheree Keller can be contacted via email at slkeller@nnu.edu, via telephone at 208-794-5501 or by writing: Sheree Keller, 450 W. Island Ct., Nampa, ID 83686. You may also discuss questions or concerns with the research supervisor. Dr. Duane Slemmer can be contacted via email at dlslemmer@nnu.edu, or via telephone at 208-467-8039.

Should you feel distressed due to participation in this, you should contact your own health care provider.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on your present or future status as a professional.

I give my consent to participate in this study:

Signature of Study Participant **Date**

I give my consent for the interview and discussion to be audio recorded in this study:

Signature of Study Participant **Date**

I give my consent for direct quotes to be used in this study:

Signature of Study Participant **Date**

Signature of Person Obtaining Consent **Date**

THE NORTHWEST NAZARENE UNIVERSITY INSTITUTIONAL REVIEW BOARD HAS REVIEWED THIS PROJECT FOR THE PROTECTION OF HUMAN PARTICIPANTS IN RESEARCH.

Appendix I

Danielson Classroom Observation Instrument

Component	Unsatisfactory	Basic	Proficient	Distinguished
2a – Creating an Environment of Respect and Rapport	Patterns of classroom interactions, both between teacher and students and among students are mostly negative, inappropriate, or insensitive to students' ages, cultural backgrounds and developmental levels. Student interactions are characterized by sarcasm, put-downs, of conflict. The teacher does not deal with disrespectful behavior.	Patterns of classroom interaction, both between teacher and students and among students, are generally appropriate but may reflect occasional inconsistencies, favoritism, and disregard for students' ages, cultures, and developmental levels. Students rarely demonstrate disrespect for one another. The teacher attempts to respond to disrespectful behavior, with uneven results. The net result of the interactions is neutral, conveying neither warmth or conflict.	Teacher-student interactions are friendly ad demonstrate general caring ad respect. Such interactions are appropriate to the ages, cultures, and developmental levels of the students. Interactions among students are generally polite and respectful, and students exhibit respect for the teacher. The teacher responds successfully to disrespectful behavior among students. The net result of the interactions if polite, respectful, and businesslike, though students may be somewhat cautious about taking intellectual risks.	Classroom interactions between teacher and students and among students are highly respectful, reflecting genuine warmth, caring, and sensitivity to students as individuals. Students exhibit respect for the teacher and contribute to high levels of civility among all members of the class. The new result is an environment where all students feel valued and are comfortable taking intellectual risks.
2b – Establishing a Culture for Learning	The classroom culture is characterized by a lack of teacher or student commitment to learning, and/ or little or no investment of student energy in the task at hand. Hard work and the precise use of language are not expected or valued. Medium to low expectations for student achievement are the norm, with high	The classroom culture is characterized by little commitment to learning by the teacher or students. The teacher appears to be only "going through the motions," and students indicate that they are interested in the completion of a task rather than the quality of the work. The teacher conveys that student success is the result	The classroom culture is a place where learning is valued by all; high expectations for both learning and hard work are the norm for most students. Students understand their role as learners and consistently expend effort to learn. Classroom interactions support learning, hard work,	The classroom culture is a cognitively busy place, characterized by a shared belief in the importance of learning. The teacher conveys high expectations for learning for all students and insists on hard work; students assume responsibility for high quality by initiating improvements, making

	expectations for learning reserved for only one or two students.	of natural ability rather than hard work, and refers only in passing to the precise use of language. High expectations for learning are reserved for those students thought to have a natural aptitude for the subject.	and the precise use of language.	revisions, adding detail, and/or assisting peers in their precise use of language.
3a – Communicating with Students	The instructional purpose of the lesson is unclear to students, and the directions and procedures are confusing. The teacher's explanation of the content contains major errors and does not include any explanation of strategies students might use. The teacher's spoken or written language contains errors of grammar or syntax. The teacher's academic vocabulary is inappropriate, vague, or used incorrectly, leaving students confused.	The teacher's attempt to explain the instructional purpose has only limited success, and/or directions and procedures must be clarified after initial student confusion. The teacher's explanation of the content may contain minor errors; some portions are clear, others difficult to follow. The teacher's explanation does not invite students to engage intellectually or to understand strategies they might use when working independently. The teacher's spoken language is correct but uses vocabulary that is either limited or not fully appropriate to the students' ages or backgrounds. The teacher rarely takes opportunities to explain academic vocabulary.	The instructional purpose of the lesson is clearly communicated to students, including where it is situated within broader learning; directions and procedures are explained clearly and may be modeled. The teacher's explanation of content is scaffolded, clear, and accurate and connects with students' knowledge and experience. During the explanation of content, the teacher focuses, as appropriate, on strategies students can use when working independently and invites student intellectual engagement. The teacher's spoken and written language is clear and correct and is suitable to students' ages and interests. The teacher's use of academic vocabulary is precise and serves to extend student understanding.	The teacher links the instructional purpose of the lesson to the larger curriculum; the directions and procedures are clear and anticipate possible student misunderstanding. The teacher's explanation of content is thorough and clear, developing conceptual understanding through clear scaffolding and connecting with students' interests. Students contribute to extending the content by explaining concepts to their classmates and suggesting strategies that might be used. The teacher's spoken and written language is expressive, and the teacher finds opportunities to extend students' vocabularies, both within the discipline and for more general use. Students contribute to the correct use of academic vocabulary

3b – Using Questioning and Discussion Techniques	Questions are rapid-fire and convergent, with a single correct answer. Questions do not invite student thinking. All discussion is between the teacher and students; students are not invited to speak directly to one another. The teacher does not ask students to explain their thinking. Only a few students dominate the discussion.	The teacher frames some questions designed to promote student thinking, but many have a single correct answer, and the teacher calls on students quickly. The teacher invites students to respond directly to one another's ideas, but few students respond. The teacher calls on many students, but only a small number actually participate in the discussion. The teacher asks students to explain their reasoning, but only some students attempt to do so.	The teacher uses open-ended questions, inviting students to think and/or offer multiple possible answers. The teacher makes effective use of wait time. Discussions enable students to talk to one another without ongoing mediation by teacher. The teacher calls on most students, even those who don't initially volunteer. Many students actively engage in the discussion. The teacher asks students to justify their reasoning, and most attempt to do so.	Students initiate higher-order questions. The teacher builds on and uses student responses to questions in order to deepen student understanding. Students extend the discussion, enriching it. Students invite comments from their classmates during a discussion and challenge one another's thinking. Virtually all students are engaged in the discussion
3c – Engaging Students in Learning	Few students are intellectually engaged in the lesson. Learning tasks/activities and materials require only recall or have a single correct response or method. Instructional materials used are unsuitable to the lesson and/or the students. The lesson drags or is rushed. Only one type of instructional group is used (whole group, small groups) when variety would promote more student engagement.	Some students are intellectually engaged in the lesson. Learning tasks are a mix of those requiring thinking and those requiring recall. Student engagement with the content is largely passive; the learning consists primarily of facts or procedures. The materials and resources are partially aligned to the lesson objectives. Few of the materials and resources require student thinking or ask students to explain their thinking. The pacing of the lesson is uneven—suitable in parts but rushed or dragging in others. The instructional groupings used are partially appropriate to the activities.	Most students are intellectually engaged in the lesson. Most learning tasks have multiple correct responses or approaches and/or encourage higher-order thinking. Students are invited to explain their thinking as part of completing tasks. Materials and resources support the learning goals and require intellectual engagement.	Virtually all students are intellectually engaged in the lesson. Lesson activities require high-level student thinking and explanations of their thinking. Students take initiative to adapt the lesson by (1) modifying a learning task to make it more meaningful or relevant to their needs, (2) suggesting modifications to the grouping patterns used, and/or (3) suggesting modifications or additions to the materials being used. Students have an opportunity for reflection and closure on the lesson to consolidate their understanding.

3d – Using Assessment in Instruction	The teacher gives no indication of what high-quality work looks like. The teacher makes no effort to determine whether students understand the lesson. Students receive no feedback, or feedback is global or directed to only one student. The teacher does not ask students to evaluate their own or classmates' work.	There is little evidence that the students understand how their work will be evaluated. The teacher monitors understanding through a single method, or without eliciting evidence of understanding from students. Feedback to students is vague and not oriented toward future improvement of work. The teacher makes only minor attempts to engage students in self- or peer assessment.	The teacher makes the standards of high-quality work clear to students. The teacher elicits evidence of student understanding. Students are invited to assess their own work and make improvements; most of them do so. Feedback includes specific and timely guidance, at least for groups of students.	Students indicate that they clearly understand the characteristics of high-quality work, and there is evidence that students have helped establish the evaluation criteria. The teacher is constantly "taking the pulse" of the class; monitoring of student understanding is sophisticated and continuous and makes use of strategies to elicit information about individual student understanding. Students monitor their own understanding, either on their own initiative or as a result of tasks set by the teacher. High-quality feedback comes from many sources, including students; it is specific and focused on improvement.

Appendix J

Administrator Interview Protocol

Thank you once again for your willingness to participate in the interview portion of my study. As I mentioned before, my study seeks to understand the professional growth of Idaho math teachers as defined by the Danielson Framework for Teaching. Our interview today will last approximately 30 minutes during which time I will ask you questions related to your perspectives of lesson study.

Prior to the interview you completed a consent form indicating that I have your permission to audio record our conversation. Are you still ok with me recording our interview?

If yes: Thank you! Please let me know if at any point to you want me to turn off the recorder or keep something you said off the record.

If no: Thank you for letting me know. I will only take notes during our conversation.

Before we begin the interview, do you have any questions?
Feel free to ask if any questions arise at any point in the study. I would be happy to discuss them with you.

Introductory Questions:

- What is your name?
- How long have you been an administrator at *school*?
- What grade/subject did you teach prior to becoming an administrator?

Transition Questions:

- How long has your school been involved in lesson study?
- How did your school become involved in lesson study?

Key Questions:

1. What has been the biggest change you have seen in math instruction since your school began participating in lesson study?
2. How participation in lesson study impacted your math teachers' professional growth?

<u>These questions can be used as follow up as needed:</u>

3. How has the learning culture in your math classrooms been impacted? (2b)
4. How have the teachers' explanations of mathematical content been impacted? (3a)
5. How have the students' explanations of mathematical content been impacted? (3a)

6. How has student discourse been impacted? (3b)
7. How has student engagement in complex tasks been impacted? (3c)
8. How has your teachers' ability to diagnose evidence of student learning been impacted? (3d)
9. Is there any evidence that lesson study with teachers can impact student achievement?

Closing Questions:

- Before we conclude the interview, is there anything about your experience with lesson study that you would like to add?
- Is there anything else that would be useful for me to know?

Thank you so much for your participation today! This information will help us better understand the professional development needs of math teachers in Idaho. I will follow up via email summarizing our discussion today. You will have an opportunity to verify that the interview summary accurately represents your views.