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Lesson study design features for supporting collaborative teacher learning

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HIGHLIGHTS

- The facilitator's focus on student thinking is important for an effective inquiry process.
- High quality materials are necessary for an effective inquiry process.
- A long-term process of lesson study is important for an effective inquiry process.
- An effective inquiry process is associated with positive teacher learning outcomes.

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ABSTRACT

Teacher learning communities have been promoted as a promising approach to promote systemwide improvement of teaching and student learning. However, our knowledge about what design features of collaborative learning processes in teacher groups support teacher learning is still limited. Based on a teacher survey of lesson study, this study found that facilitators' focus on student thinking, the quality of materials, and duration of lesson study were significantly associated with teacher participation in an effective inquiry process, which in turn is associated with perceived positive changes in teacher knowledge, self-efficacy, and expectation.

1. Introduction

Teacher learning communities (TLCs) where teachers share norms, values, and practices for a common goal of supporting student learning have been promoted as a promising approach to systemwide improvement of instruction and student learning during the last two decades (Cochran-Smith & Lytle, 1999; Grossman, Wineburg, & Woolworth, 2001; Louis & Marks, 1998; McLaughlin & Talbert, 2001, 2006; Westheimer, 1998). As a result, TLCs such as lesson study and Professional Learning Communities (PLCs) have become a popular approach around the globe (Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Vescio, Ross, & Adams, 2008). In particular, lesson study—a teacher driven, collaborative inquiry process of studying curriculum, teaching and student learning—has gained the attention of educators, administrators and policymakers as an international innovation originated in Japan (Editorial Projects in Education, 2012; Lewis & Lee, 2018), leading to an establishment of the World Association of Lesson Studies in 2006. Lesson study has been increasingly practiced in the U.S. (Akiba & Wilkinson, 2016; Lewis, Perry, Hurd, & O'Connell, 2006; Perry & Lewis, 2009), United Kingdom (Dudley, 2015), and many other countries (World Association of Lesson Studies, n.d.).

Benefits of TLCs have been empirically demonstrated in the U.S. by prior research that established the association between teacher collaboration and student achievement growth using large-scale survey methods (Akiba & Liang, 2016; Doppenberg, den Brok, & Bakx, 2012; Goddard, Goddard, & Tschannen-Moran, 2007; Ronfeldt, Farmer, McQueen, & Grissom, 2015) and experimental or quasi-experimental studies on collaboration-focused teacher professional development programs that improved student

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achievement (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Saunders, Goldenberg, & Gallimore, 2009; Saxe, Gearhard, & Nasir, 2001).

However, we still have limited empirical evidence regarding which design features of TLCs such as lesson study promote teacher learning. Existing studies paid attention to the focus of collaborative teacher learning activities such as instruction, student, and assessment (Doppenberg et al., 2012; Ronfeldt et al., 2015), structure of collaboration such as use of a protocol (Levine & Marcus, 2010; Saunders et al., 2009), and the role of resources available to teachers (Lewis & Perry, 2014, 2017). The current study builds on these prior studies and examines other policy-relevant design elements that were not yet examined together—duration, facilitator orientation, and material quality—based on survey data gathered from teachers in lesson study groups.

We examined the relationship among these design features, teacher participation in an effective inquiry process of lesson study (studying curriculum and student thinking on a specific topic, planning a lesson with anticipation of student responses, gathering data during a live lesson with students, and analyzing and discussing student responses and teaching effectiveness), and teacher learning outcomes, measured by perceived changes in knowledge, self-efficacy, and expectation. Based on survey data collected from 87 teachers in 24 teacher groups who engaged in mathematics lesson study during the 2015-16 academic year in Florida, we addressed the following research questions:

1. What are the variations in design features (duration, facilitator orientation, and material quality) and teacher participation in an effective inquiry process in mathematics lesson study?
2. How are design features associated with teacher learning outcomes measured by perceived changes in knowledge, self-efficacy, and expectation, mediated by teacher participation in an effective inquiry process in mathematics lesson study?

This study responds to a call to examine specific professional development designs to better inform future investment and support for teacher learning (Hill, Beisiegel, & Jacob, 2013; Wayne, Yoon, Zhu, Cronen, & Garet, 2008). Identifying which design features of collaborative teacher learning are associated with positive teacher learning outcomes based on a natural variation of design features employed in a teacher-driven, collaborative, inquiry process of lesson study in Florida will inform districts' and schools' decisions about where to invest so that they can maximize limited resources available for professional learning.

2. Background

2.1. Theoretical framework: teacher learning communities (TLCs)

Various researchers have defined TLCs (Grossman et al., 2001; Learning Forward, 2011; Stoll et al., 2006; Westheimer, 1998). Westheimer (1998), for example, identified five common themes based on social theories of community—interaction and participation, interdependence, shared interests and beliefs, concern for individual and minority views, and meaningful relationships. Similarly, Stoll et al. (2006) described five key characteristics of PLCs as shared values and vision, collective responsibility, reflective professional inquiry, collaboration, and group learning. In the Standards for Professional Learning, Learning Forward (n.d.) defined learning communities with three characteristics—commitment to continuous improvement, collective responsibility for the learning of all students, and alignment of individual, team, school, and school system goals.

What is common in these definitions is a vision of TLCs where teachers come together based on the shared goal of supporting student learning and engage in collaborative learning where reflective dialogues based on different views are valued and promoted for continuous improvement of student learning. In such communities, teachers develop meaningful relationships with one another and assume collective responsibility for continuous professional learning about teaching and student learning.

Despite the promise and popularity of TLCs, however, the studies that examined the development and practice of TLCs have identified major challenges (Achinstein, 2002; Grossman et al., 2001; Hargreaves, 1991; Horn, Garner, Kane, & Brasel, 2017; Horn & Little, 2010; Little, 1990; McLaughlin & Talbert, 2001). Grossman et al. (2001) argued that, compared to medicine or law, the field of education has not established shared language and values, and professional learning for deepening knowledge of subject matter is not embedded into teachers' work schedule. The occupational norms of privacy and autonomy in teaching in the U.S. continue to impede authentic joint work among teachers (Little, 1990; Lortie, 1975). When such collaborative learning opportunities are given, teachers often fail to negotiate the tension that naturally arises from a group of teachers with diverse backgrounds, beliefs, and values (Achinstein, 2002; Grossman et al., 2001), experiencing a contrived collegiality (Hargreaves, 1991) or a pseudo-community characterized by the imperative to "behave as if we all agree" (Grossman et al., 2001).

Even when teachers successfully form a learning community with shared norms and values for supporting student learning, studies have found that those values may not be aligned with the reform vision of promoting student understanding (McLaughlin & Talbert, 2001) or dialogues within the community may not provide rich learning opportunities for teachers (Horn et al., 2017; Horn & Little, 2010). In their study of 16 high schools, McLaughlin and Talbert (2001) found that not all strong professional communities have an orientation to move beyond the traditional teacher-centered view of teaching or are even concerned with improvement. Horn and Little (2010) compared two teacher work groups in the same high school and found that the conversational routine of normalizing, specifying, revising, and generalizing using vivid examples of teaching (replay and rehearsal) afforded rich learning opportunities in one group, while the other group failed to do so. Horn et al. (2017) further examined conversational processes of 24 groups and found that only 10 groups had at least one meeting that involved a collective interpretation of teaching that allowed rich dialogue for developing pedagogical concepts.

These studies have shown that TLCs that provide rich learning opportunities for teachers to deepen pedagogical content knowledge and develop instruction consistent with reform visions are still rare (Bausmith & Barry, 2011; Curry, 2008). There is a need to understand what differentiates the TLCs that afford such rich learning opportunities and the other communities that fail to do so.

2.2. Empirical studies on collaborative teacher learning

Previous quantitative studies on collaborative teacher learning either applied survey methods (Doppenberg et al., 2012; Ronfeldt et al., 2015) or conducted experimental or quasi-experimental studies of collaboration-based teacher professional development programs (Heller et al., 2012; Saunders et al., 2009; Saxe et al., 2001). Using survey data from 9000 teachers in 336 schools in Miami, Ronfeldt et al. (2015) found that a foci on students and assessment and focus on instruction were significantly associated with higher value-added scores in mathematics and reading respectively. Doppenberg et al. (2012) analyzed survey data from 411 teachers from 49 primary schools in the Netherlands and found that teacher groups that focused on implementing a new teaching approach tended to report a greater perceived level of individual and collegial learning than groups that focused on implementing new lesson materials or teaching a particular group of students. While these studies identified promising collaboration foci, their implications may be limited as TLCs often discuss multiple aspects of teaching and student learning, including curriculum, instructional approaches, assessment, and student thinking instead of choosing one over another.

Saunders et al. (2009) conducted a quasi-experimental study of grade-level teams in 15 Title I schools and found that experimental schools that used explicit protocols focused on students' needs and how to instructionally address them improved student achievement more than control schools. Saxe et al. (2001) examined three conditions for mathematics curriculum implementation and found that only the condition with specific foci on teachers' content knowledge, student thinking and motivation improved student achievement. Focusing on elementary science, Heller et al. (2012) compared the impacts of collaboration-based professional development programs and found that Teaching Cases and Looking at Student Work, which focused on analysis of student work and classroom tasks that reveal students' conceptual understanding, improved conceptual knowledge of teachers and students. These findings are consistent with a synthesis of eleven studies on PLCs conducted by Vescio et al. (2008) that reported the importance of a consistent focus on student learning and instructional strategies.

These empirical studies and synthesis consistently showed that a specific focus on student thinking and instruction that reveals and deepens students' conceptual understanding improves student achievement. Accordingly, it is important to identify the conditions that focus teacher discourses on student thinking and instruction during collaboration. Using a specific protocol is one approach as identified by Saunders et al. (2009), as well as in a case study of one teacher group conducted by Levine and Marcus (2010) and a study of six school-based inquiry groups called "Critical Friends Groups" conducted by Curry (2008). Lesson study provides the structure to focus teacher discourses on student thinking and instruction through four stages of studying, planning, teaching, and discussing, but little is known about the impacts of other important conditions that influence teacher discourses such as the role of facilitators and material quality on teacher learning outcomes.

2.3. Design features of lesson study

Lesson study originates in Japan and has been practiced by Japanese teachers for over a century (Fernandez & Yoshida, 2004; Makinae, 2010). It has spread globally since the late 1990s when *The Teaching Gap* by Stigler and Hiebert (1999) introduced lesson study as a system that supports Japanese teachers' practice of high quality instruction. In lesson study, a group of teachers engage in four stages of: 1) studying the curriculum and student understanding in a chosen topic—a topic their students struggle with—and setting a student learning goal, 2) developing a research lesson that anticipates student responses and learning, 3) teaching the research lesson in a classroom of one group member while others gather data on student responses and thinking processes, and 4) discussing the effectiveness of the lesson in promoting student learning (Hart, Alston, & Murata, 2011; Lewis & Hurd, 2011).

A major strength of lesson study as a professional learning process is the enactment of teaching as part of the learning process through a research lesson. Previous studies have documented the critical importance of enactment of teaching for changing teachers' belief systems (Clarke & Hollingsworth, 2002; Guskey, 1986) and have promoted embedding teacher learning into daily teaching practice and using student work as a tool for collaborative teacher learning (Ball, Ben-Peretz, & Cohen, 2014; Ball & Cohen, 1999; Kazemi & Franke, 2004; Kazemi & Hubbard, 2008; Little, 2002). Research lessons in lesson study can allow teachers to experience and observe changes in student learning as a result of the collectively designed instructional approach. This may create a cognitive conflict or dissonance which leads to changes in teacher beliefs about teaching and learning (Cohen & Ball, 2001; Opfer & Pedder, 2011).

Despite a structure that focuses teacher discourses on student thinking and instruction, the implementation of lesson study in the U.S. has proven to be challenging for various reasons. First, the heavy instructional load of U.S. teachers does not allow sufficient time to engage in a continuous inquiry process of lesson study without extra funding to create common meeting time (Murata, 2011; Yoshida, 2012). Second, teachers' lack of familiarity with a research process of studying curriculum, collecting and interpreting data, and drawing conclusions and implications for teaching and student learning challenges the teacher-driven inquiry process (Fernandez, Cannon, & Chokski, 2003; Hart, 2009; Yoshida, 2012). Finally, the limited content and pedagogical content knowledge of many teachers poses a challenge for engaging in in-depth discussion of student thinking and teaching (Yoshida, 2012).

These challenges can possibly be mitigated by district and school investment in material and human resources for ensuring sufficient time for teachers, developing and supporting facilitators who can focus teacher dialogues on student thinking and teaching, and using high quality materials to deepen content and pedagogical content knowledge (e.g., Fernandez et al., 2003; Perry & Lewis, 2009). Previous studies point to the promise of investing in these three conditions—duration, facilitator, and materials—as design features of lesson study.

First, the provision of sufficient meeting time is critical for teacher groups to engage in a continuous inquiry process of studying student thinking and experimenting with instructional approaches (Murata, 2011; Yoshida, 2012). However, due to the heavy instructional load of U.S. teachers compared to teachers in other countries (Liang & Akiba, 2018),[1] lesson study has often been practiced as a relatively short-term professional development to make it manageable (Akiba & Wilkinson, 2016). It is important to examine how the duration of lesson study—both in terms of time span and total amount spent—are associated with teacher participation in an effective inquiry process as well as teacher learning outcomes.

Second, facilitators with expert knowledge can play a critical role in supporting teachers who are not familiar with the research process and who possess limited content and pedagogical content knowledge by leading a collective inquiry into curriculum, student work, and instructional approaches in lesson study (Chokshi & Fernandez, 2004; Fernandez & Cannon, 2005; Fernandez et al., 2003; Perry & Lewis, 2009). Borko (2004) identified facilitators as a critical element of a professional development system, and various professional development programs have focused on cultivating teacher leadership to facilitate other teachers' learning (Borko, Koellner, & Jacobs, 2014; Elliott et al., 2009; Kazemi et al., 2011; Koellner, Jacobs, & Borko, 2011). These studies indicate the importance of two foci of facilitation—student thinking and active teacher participation.

When the facilitator focuses on engaging teachers in in-depth discussion of students' mathematical thinking, teachers will be able to make connections among student learning, content, and

[1] According to the 2013 Teaching and Learning International Survey (TALIS), U.S. teachers spend 26.3 hrs a week for instruction, significantly more than the international average of 19.5 hrs across 32 countries and 17.6 hrs in Japan (Liang & Akiba, 2018).

teaching (Murata, Bofferding, Pothen, Taylor, & Wischnia, 2012) and develop a lesson where the instructor orchestrates a productive student discussion of various solutions representing students' mathematical thinking (Murata et al., 2017; Smith & Stein, 2011; Stein, Engle, Smith, & Hughes, 2008). The critical role of facilitators was also identified in shaping the quality of inquiry around student learning data in teacher collaboration (Slavit, Nelson, & Deuel, 2013) and in supporting an effective conversational routine by posing questions, eliciting specific accounts of teaching practice, and focusing teacher discourses on student and teacher learning (Horn & Little, 2010).

In addition, when the facilitator actively involves teachers by encouraging them to share their experience and perspectives and valuing their input, teachers will be able to engage in active learning (Desimone, 2009; Loucks-Horsley et al., 1998; Wilson & Berne, 1999). Active learning facilitates teachers' reflections on their beliefs about teaching and student learning, and previous research has shown that active learning opportunities were associated with an increase in teachers' practice of higher-order instruction (Desimone, Porter, Garet, Yoon, & Birman, 2002). However, a prior experimental study on collaborative professional development (Saxe et al., 2001) and qualitative studies on teacher discourses (Horn et al., 2017; Horn & Little, 2010; McLaughlin & Talbert, 2001) showed that providing collegial support alone does not necessarily lead to changes in teacher beliefs or improved student achievement. There is a need to investigate how the orientation of the facilitators toward student thinking and active teacher participation is associated with teacher learning outcomes.

Finally, limited access to high quality resource materials during lesson study affects teachers' learning opportunities for understanding student thinking, developing instructional approaches with high cognitive demands, and analyzing and interpreting students' mathematical thinking and ideas. Lewis and Perry (2014, 2017) conducted a randomized field trial of 39 lesson study groups across the U.S. and found that teachers in experimental lesson study groups who were supported by rich mathematics resources improved their knowledge and student achievement more than the control group teachers. Rich resources for understanding content standards relevant to the chosen topic, how the chosen topic builds across grade levels, various instructional approaches for a student-centered, problem-solving lesson, and students' mathematical learning progressions are necessary for supporting lesson study groups' inquiry process (Watanabe, 2007; Watanabe, Takahashi, & Yoshida, 2008).

In summary, these three design features—duration, facilitator foci on student thinking and active teacher participation, and material quality—constitute critical support conditions for teacher groups to engage in an effective inquiry process of lesson study. However, no previous empirical studies examined these policy-relevant design features for supporting teacher engagement in lesson study together.

2.4. Teacher learning outcomes of lesson study

This study focuses on three learning outcomes reported by teachers—perceived changes in knowledge, self-efficacy, and expectations for students—after engagement in lesson study. We focus on perceived changes because previous studies have theorized that changes in teachers' beliefs occur when teachers experiment with a new instructional approach and gain evidence of improvement in their students' learning (Clarke & Hollingsworth, 2002; Guskey, 1986). These changes are likely long-lasting as they represent changes in the belief system that shapes teachers' daily teaching practice (Clarke & Hollingsworth, 2002; Horn, 2007). Such perceived changes also likely increase motivation for continuously engaging in professional learning in the future (Karabenick & Conley, 2011). It is important to note, however, that perceived changes are not the same as actual changes as previous research has shown the discrepancy between teachers' perception of instructional quality and the actual quality (e.g., Cohen, 1990).

Despite this limitation, examining teachers' perceptions—-knowledge growth, self-efficacy, and expectation—is an important first step for understanding how their learning experience through lesson study influences their knowledge and practice. When teachers perceive that their participation in lesson study improved their knowledge it is likely that they benefit from that learning experience, which would, in turn, continue to motivate them to engage in lesson study to improve their knowledge and instructional practice (Karabenick & Conley, 2011; Nolen, Ward, & Horn, 2014).

A perception of knowledge growth through participation in lesson study would also likely improve teacher self-efficacy (Puchner & Taylor, 2006). Previous empirical studies have found that well-designed professional development programs can help improve teacher self-efficacy (Carney, Brendefur, Thiede, Hughes, & Sutton, 2016; Ross & Bruce, 2007; Zambo & Zambo, 2008). Observing that their students learned better during the research lesson, teachers may foster the self-efficacy belief that their engagement in continuous inquiry into curriculum, student thinking, and instructional approaches will help improve their teaching and student learning.

Finally, by observing their students share various ideas in response to a problem-solving task, teachers may realize that their students can solve challenging problems and it is important to hold them to higher expectations. In a qualitative study of two lesson study groups, Puchner and Taylor (2006) found that teachers elevated their appraisal of students' mathematical abilities after observing a successful research lesson. Wilson, Sztajn, Edgington, Webb, and Myers (2017) also found that a professional development focus on student learning trajectory changed their beliefs about the sources of student performance from age, grade, or ability to learning opportunities provided to students.

2.5. Conceptual model

Fig. 1 illustrates the relationships among three design features, teacher participation in an effective inquiry process, and teacher learning outcomes, which will be empirically tested in this study. We measure teacher participation in an effective inquiry process to capture the ideal characteristics of the inquiry process across lesson study's four stages of goal setting, lesson planning, research lesson, and debriefing, as identified in the previous literature (Hart et al., 2011; Lewis & Hurd, 2011). Teacher participation in an effective inquiry process, in turn, is hypothesized to be associated with perceived positive changes in teacher knowledge, self-efficacy, and expectation.

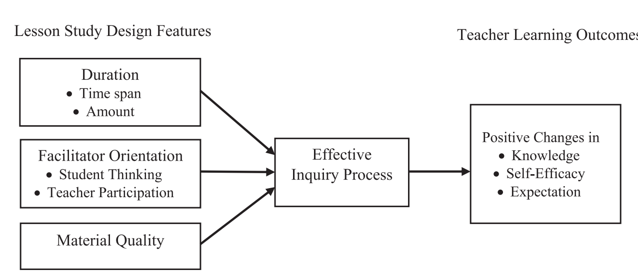

Fig. 1. Lesson study design features, teacher participation in an effective inquiry process, and teacher learning outcomes.

Identifying the relative sizes of the relationships between these design features and leaning outcomes mediated by participation in an effective inquiry process is especially important as these three design features require resources that are in short supply in most district and school contexts. A longer duration of lesson study requires more funding for substitutes for meeting during the regular school hours and teacher payment for meeting outside the contract time. Supporting effective facilitation may require special learning opportunities for teacher leaders who are serving as facilitators of lesson study. Providing high quality materials may require collaboration with researchers or professional developers who can provide research-based materials. If one design feature is found to be more strongly associated with positive learning outcomes compared to others, district or school resources could be invested in the effective design feature as a promising condition for producing a maximum return.

3. Methods

3.1. Survey context

This study was conducted as part of a larger 4-year project that examined the effective and scalable design features of lesson study in Florida through district surveys, facilitator and teacher surveys, and case studies of lesson study groups. It was conducted in Florida where the Florida Department of Education (FLDOE) promoted lesson study as a vehicle for implementing new state standards aligned with the Common Core State Standards using part of the US$700 million Race to the Top (RTTT) funding they received in 2009 (FLDOE, 2010a, 2010b, n.d.). Lesson study has spread across the state in response to the FLDOE's requirement to implement lesson study in persistently lowest achieving (PLA) schools.

Lesson study was introduced by FLDOE to districts with PLA schools as "an ongoing professional development process utilized within Professional Learning Communities (PLCs) to allow teachers the opportunity to create a model for high-quality instructional practices" with four phases of: (1) scheduling and planning, (2) teaching and observing, (3) debriefing and improving, and (4) reteaching and reflecting (Haithcock, 2010, p. 4). School districts with PLA schools were required to provide training on lesson study to schools, yet the degree and scale of implementation was left to districts' discretion (Haithcock, 2010). Thus, each district or each school in some cases determined specific approaches to lesson study including the number of cycles, duration of each cycle, the type and quality of materials used for lesson planning, and facilitators (i.e. who serves as facilitators and whether to provide training for facilitators). This resulted in a major variation across lesson study groups in the specific design features.

A statewide longitudinal survey of district professional development coordinators reported that a total of 668 schools in 46 districts and 749 schools in 39 districts practiced lesson study during the 2013-14 and 2014-15 academic years respectively (Akiba et al., 2016). This study focused on teacher survey data collected from 87 teachers in 24 lesson study groups. A survey method was used to examine the statistical relationships between design features of lesson study and teacher learning outcomes.

3.2. Data collection method

From November 2015 to February 2016, the project team contacted the professional development coordinators of 27 districts in Florida who reported a practice of lesson study in at least 5 schools in the prior year (2014–15). After submitting a research request to each of the 27 districts following the district-specific application process, 7 districts declined to participate because no school practiced lesson study in mathematics (but in another subject area). Another 14 districts either did not respond or communicated that their districts do not allow surveys of school personnel to protect their time. A new teacher evaluation system with value-added data was implemented in the same year, which may explain districts' reluctance to participate in projects that demand teachers' time.

By February 2016, six districts agreed to participate in the survey, and researchers contacted the principals or lesson study facilitators in each district to compile a list of lesson study group members and meeting schedules. Based on the meeting schedules, we confirmed that all groups went through the four stages of lesson study. The information of 110 teachers in 24 groups were provided by March 2016, and a link to a Qualtrics online survey, "Lesson Study Teacher Survey" was emailed to each teacher between March 2016 to August 2016. The survey communicated the confidential and voluntary nature of their participation and the incentive of a $20 online gift card. A total of 87 teachers from 24 lesson study groups in six districts completed the survey with a response rate of 79%.

The poverty and diversity levels of the schools measured by the percentages of students receiving free or reduced-price lunch and ethnic minority students ranged from 34% to 100% with a mean of 60% and from 10% to 80% with a mean of 36% respectively. The poverty level of these schools is comparable to the state mean of 63%, but participating schools enrolled fewer minority students than the state average of 49%. Eight groups were located in secondary schools (middle or high schools) and 16 groups in elementary schools. Teaching experience ranged from 0 to 42 years with an average of 13.3 years, and 10.3% of teachers majored in mathematics and 23.0% majored in mathematics education.

3.3. Variables

The survey first asked teachers to report the number of mathematics lesson study cycles they participated in during the 2015-16 academic year. 79% of teachers reported that they participated in one cycle, 14% in two cycles, 6% in three cycles, and 1% in five cycles. This may be explained by our previous finding that most districts do not provide funding for substitutes that are required for research lessons (Akiba & Wilkinson, 2016). Teachers who participated in multiple cycles were asked to choose one cycle that influenced them the most in completing the survey. Appendix lists all survey questions, response choices and coding, and reliability indices (Cronbach alpha) for composite variables.

All survey items were developed by the first author with expertise in survey item development. Original survey items were developed because no previously validated survey items on lesson study design features and inquiry process exist, and existing survey scales on teacher learning outcomes such as self-efficacy are too general for the purpose of this study. All survey items were pilot tested for content validity and reliability in 2013 following three stages (Dillman, Smyth, & Christian, 2014; Fowler, 2014). First, the researcher sought detailed feedback on the draft survey items from three researchers with content expertise in lesson study, professional development, and survey methods. Second, the researcher administered the pilot survey to 42 teachers who are mathematics lesson study participants with a section on narrative feedback on the items that were difficult or confusing. Finally, the pilot data were analyzed statistically and items that lowered the reliability of a scale were removed. The items that were reported as difficult to understand or confusing were also revised to clarify the content and to accurately measure the survey construct. High reliability index values in the Appendix show that all the scales are reliable.

3.3.1. Lesson study design features and an effective inquiry process

Duration was measured using two variables based on facilitators' report of the lesson study meeting schedule. The time span of lesson study was measured by the number of days between the first lesson study meeting to the last meeting, and the amount of lesson study was the total numbers of hours spent for lesson study including studying, planning, research lesson, and debriefing. Due to the high correlation between these two variables (Pearson $r = .80$), a composite variable of duration was created by standardizing both variables and taking the mean based on the reason that these two variables consistently measure the duration of lesson study.

Facilitator orientation was measured by two composite variables: (1) focus on student thinking and (2) focus on active teacher participation. For measuring facilitator focus on student thinking, a mean of teacher responses to four survey items on the extent to which their facilitators led an in-depth discussion of various student solutions and anticipated student responses, an analysis of students' mathematical thinking, and a review of students' learning progressions were computed. For example, in lesson study meetings, the facilitator may ask teachers to bring student work samples of a specific content topic from their own classrooms, sort them by different strategies students used, and guide the discussion on how these strategies are different or related, and how they progress as students develop understanding of the topic. For measuring the facilitator focus on active teacher participation, a mean of three survey items on the extent to which facilitators encouraged each teacher to share prior experiences, listened carefully to and valued each member's opinions, and made sure that all teachers contributed to the discussion and lesson planning were computed.

Material quality was measured by a mean of the perceived usefulness of materials for nine learning purposes including understanding relevant standards, deepening content knowledge, learning various student-centered approaches, and anticipating students' responses. These materials, which may include readings on student thinking and instructional approaches, guides to standards, and existing lesson plans with anticipated student responses, are used to guide the lesson study process, providing research-based knowledge and instructional approaches as teachers made lesson-related decisions.

Teacher participation in an effective inquiry process was measured by a mean of 18 items asking teachers to report the extent to which their learning activities are characterized by an effective inquiry process identified by previous literature (Hart et al., 2011; Lewis & Hurd, 2011). These items measured the process of studying and lesson planning and debriefing—the process for choosing a topic; discussions of student thinking and progressions; the process of choosing a problem-solving task and anticipating student responses; developing a data collection plan during a research lesson; and discussions of student data, student learning, and effectiveness of instruction and its further improvement. Although multiple processes are included as part of this variable, we collectively refer to them as "an effective inquiry process" to measure the synergistic nature of the multiple processes identified as contributing to an effective inquiry process.[2]

3.3.2. Teacher learning outcomes

Perceived change in teacher knowledge was measured by a mean of nine items on perceived positive changes in various types of knowledge for professional learning and teaching that occurred as a result of participating in a mathematics lesson study cycle. These items included knowledge of mathematics content, various instructional approaches, and common student understandings and misconceptions.

Self-efficacy was measured by a mean of four items on perceived changes in the belief that respondents can improve teaching and student learning by studying student thinking and understanding and experimenting with various instructional approaches through lesson study. We developed our own survey items on self-efficacy to measure the specific aspects of self-efficacy in the context of lesson study, including investigation of student thinking and experimentation of instructional approaches. Existing measures used in previous studies, such as the Teachers' Sense of Efficacy Scale (Tschannen-Moran & Woolfolk Hoy, 2001) and the Collective Efficacy Questionnaire (Goddard, Hoy, & Hoy, 2000), included general aspects such as classroom management and were deemed not suitable for the current study.

Expectation was measured by a mean of three items on perceived changes in teachers' belief that their students are capable of tackling a challenging mathematics problem, that students can learn better when they have a high expectation, and that it is important to give a challenging problem to students. These items are conceptually consistent with the elements of teacher expectations for students in a context of lesson study (Puchner & Taylor, 2006).

3.4. Data analysis

To examine variations in lesson study design features and teacher participation in an effective inquiry process of lesson study (research question 1), we used descriptive statistics. To examine the relationships between lesson study design features and teacher learning outcomes mediated by teachers' participation in an effective inquiry process (research question 2), we first conducted a correlation analysis among all the variables and a path analysis for each of the three outcome measures. A path analysis tests whether a multivariate set of data fits the hypothesized causal model involving mediators (Garson, 2012; Kline, 2010; Stage, Carter, & Amaury, 2004). Therefore, it is suitable for testing the model in Fig. 1.

To determine if we needed to control for teachers' background characteristics in the path models, we first examined the possible influence of teachers' background characteristics on three outcome variables by conducting a correlation analysis between three teacher learning outcomes and five teacher background characteristics: number of mathematics lesson study cycles teachers participated in during the survey year, teaching experience (number of years having taught), the total number of hours spent for mathematics professional development, mathematics major, and mathematics education major. Pearson r was used for the relationship between two continuous variables and Kendall's tau was used for the relationship between dichotomous variables. As none of these correlations were statistically significant,[3] we decided not to control for these variables to keep the path models parsimonious given the relatively small sample size.

In each path model, standardized coefficients and statistical significance level are reported for each path, and three goodness of fit indices—Chi-square test, Root Mean Square Error for Approximation (RMSEA), and Comparative Fit Index (CFI) were reported for

[2] Examining these items as separate factors using a factor analysis is not conceptually appropriate as different activities represented in the survey items are all an essential and necessary part of the inquiry process in lesson study.

[3] The readers may be puzzled by the lack of a significant relationship between the number of lesson study cycles and teacher learning outcomes. The finding needs to be interpreted with caution because only 18 out of 87 participated in more than one lesson study cycle.

model evaluation and revision. Non-significant chi-square value, RMSEA value of below .08, and CFI value of above .90 are used as the criteria to be considered as a good fit (Hu & Bentler, 1999; Sharma, Mukherjee, Kumar, & Dillon, 2005). Based on the goodness of fit indices on the initial model testing the hypothesized relationships in Fig. 1, additional paths were added to the model. Final path models with positive results from the goodness of fit indices were presented in figures along with R-square values for the endogenous variables (effective inquiry process and teacher learning outcomes) for the proportion of variance explained. Finally, direct, indirect and total effects of lesson study design features on each teacher learning outcome were computed to compare the impacts of design features on teacher learning outcomes. Indirect effects are computed by multiplying the coefficients for all the paths connecting the exogenous and endogenous variables, and the total effects are computed by summing the indirect and direct effects.

4. Results

4.1. Variations in design features and teacher participation in an effective inquiry process

Table 1 presents descriptive statistics of the variables of lesson study design features and teacher participation in effective inquiry process, along with teacher learning outcomes. The time span varied from 1 to 118 days, with a mean of 44.8 days or approximately 6 weeks. The amount varied from 2 to 23 hrs with a mean of 12.2 hrs. These numbers show that, on average, lesson study is practiced as a relatively short-term learning process by many of these groups but with significant variation across groups.

The facilitator orientation was measured with two foci—student thinking and active teacher participation. The mean value was 4.9 for student thinking and 5.3 for active teacher participation on a scale ranging from 1 = strongly disagree to 6 = strongly agree. On average, teachers agreed that their facilitators focused on leading an in-depth discussion of student thinking and actively engaging teachers in discussions. They also reported that materials were useful for various learning purposes with a mean of 3.3 on a scale ranging from 1 = not useful at all to 4 = very useful.

Teachers reported that their activities followed an effective inquiry process "to a medium extent" or "to large extent" with a mean of 3.5 on a scale ranging from 1 = not at all to 4 = to large extent based on 18 survey items. Although teachers reported positively in general on the lesson study design features and their participation in an effective inquiry process, the standard deviation values also showed sufficient variations across individuals in each of these variables.

4.2. Relationships among design features, effective inquiry process, and teacher learning outcomes

Before conducting a path analysis, we examined the correlations among lesson study design features, teacher participation in an effective inquiry process, and teacher learning outcomes to inform the development of path models. Table 2 reports the Pearson r correlations. All four variables on design features are significantly correlated with one another with an especially strong correlation between the two facilitation orientation variables. From teachers' perspectives, the facilitators who focus on student thinking are also likely to actively involve teachers in discussions. All four design feature variables were also strongly and significantly associated with teacher participation in an effective inquiry process. In addition, both design features and an effective inquiry process were significantly and positively associated with three teacher learning outcomes—perceived knowledge growth, self-efficacy, and expectation. The perceived knowledge growth was also strongly associated with self-efficacy, which is also strongly associated with expectation. With significant and positive correlations between independent (exogenous) variables and dependent (endogenous) variables, we proceeded with examining which variables are most strongly associated with the outcomes using path models.

We first tested the initial models based on our conceptual model in Fig. 1. Based on the goodness of fit indices for the initial models, we added direct paths between design features and teacher learning outcomes to test possible direct influences of design features on outcomes independent of the inquiry process. Adding direct paths significantly improved the models for two outcomes—knowledge growth and self-efficacy. The initial model for expectation achieved a good fit, thus no direct path was added to this model. Table 3 summarizes the goodness of fit indices—chi-square, RMSEA, and CFI for three models, and Figs. 2–4 present the final models with standardized coefficients and R^2 values. Table 3 shows that the final models for knowledge, self-efficacy and expectation meet the criteria for a good fit—non-significant chi-square value, RMSEA value of below .08, and CFI value of above .90 (Hu & Bentler, 1999; Sharma, Mukherjee, Kumar, & Dillon,

Table 1
Descriptive statistics of lesson study design features, effective inquiry process, and teacher learning outcomes (N = 87).

		Mean	SD	Min	Max
Lesson Study Design Features	Duration				
	Time Span (N of days)	44.8	44.8	1	118
	Amount (N of hours)	12.2	7.7	2	23
	Duration Composite (Standardized)	0	1	−1.06	1.37
	Facilitator Orientation (FO)				
	Student Thinking	4.9	1.2	1	6
	Active Teacher Participation	5.3	.9	1	6
	Material Quality	3.3	.7	1.25	4
Teacher Participation in an Effective Inquiry Process		3.5	.5	1.43	4
Teacher Learning Outcomes	Teacher Knowledge	4.8	1.2	1	6
	Self-Efficacy	5.3	.8	2.75	6
	Expectation	5.4	.6	3	6

Table 2
Correlations among main variables (N = 87).

		1	2	3	4	5	6	7
Lesson Study Design Feature	1. Duration							
	2. FO: Student Thinking	.47**						
	3. FO: Active Teacher Participation	.25*	.78**					
	4. Material Quality	.54**	.51**	.40**				
Teacher Participation in an Effective Inquiry Process	5. Effective Inquiry Process	.56**	.74**	.60**	.61**			
Teacher Learning Outcomes	6. Knowledge growth	.51**	.66**	.48**	.52**	.69**		
	7. Self-Efficacy	.45**	.57**	.51**	.59**	.62**	.70**	
	8. Expectation	.38**	.32**	.35**	.38**	.51**	.44**	.72**

Notes: *p <. 05, **p < .01.

Table 3
Goodness of fit of three path models.

Outcome	Model	Chi-square			RMSEA[a]	CFI[b]
		χ^2	*df*	*p*		
Knowledge	Initial	12.532	4	.014	.157	.970
	Final	4.083	3	.253	.065	.996
Self-Efficacy	Initial	15.828	4	.003	.185	.957
	Final	2.101	2	.350	.024	1.000
Expectation	Initial/Final	5.701	4	.222	.071	.993

[a] RMSEA = Root Mean Square Error of Approximation.
[b] CFI=Comparative Fit Index.

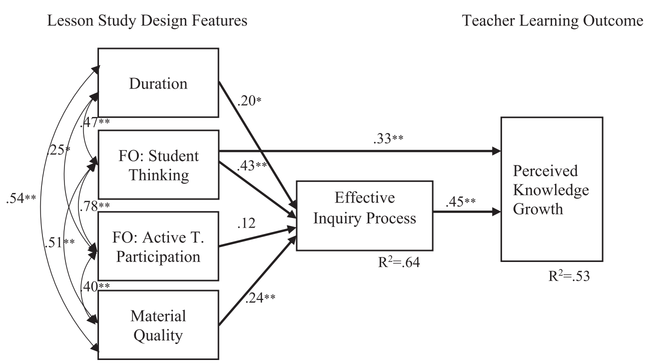

Fig. 2. Path Model with Perceived Knowledge Growth.
Notes †p < .10, *p < .05, **p < .01.

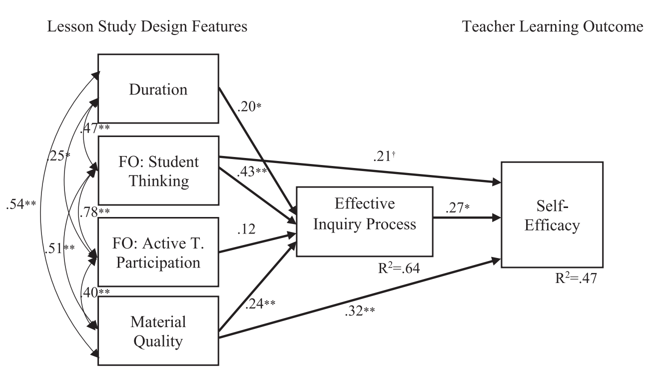

Fig. 3. Path Model with Perceived Change in Self-Efficacy.
Notes †p < .10, *p < .05, **p < .01.

2005). This means that all the final models fit the observed data, and we can be confident that the path models in Figs. 2–4 accurately display the key factors and relationships predicting the three outcomes.

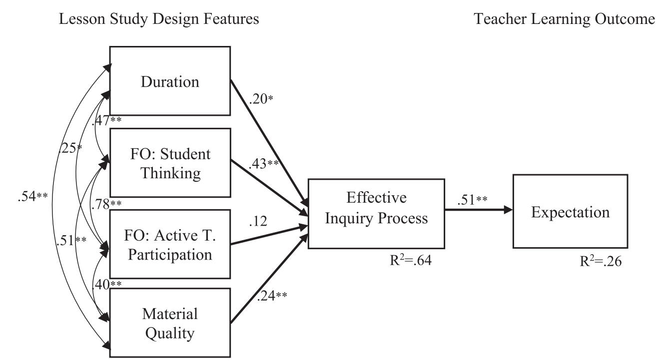

Fig. 4. Path Model with Perceived Change in Expectation.
Notes †p < .10, *p < .05, **p < .01.

Fig. 2 shows that among the four design feature variables, facilitator focus on student thinking was significantly and most strongly associated with teacher participation in an effective inquiry process. When facilitators focus on studying and discussing student thinking, learning activities tend to be characterized by an effective inquiry process of studying, lesson planning, gathering data, and analyzing and discussing student responses and teaching effectiveness. In addition, facilitators' focus on student thinking was directly associated with perceived knowledge growth. This direct effect means that when facilitators focus on student thinking, teachers report a knowledge growth even when they did not necessarily participate in an effective inquiry process of lesson study.

The duration of lesson study and perceived material quality were also significantly associated with teacher participation in an effective inquiry process. When a lesson study group spends more hours across a longer time span and uses materials perceived to be useful by teachers, teachers report that they participated in an effective inquiry process. Teacher participation in an effective inquiry process, in turn, is significantly and positively associated with a perceived knowledge growth after completing a lesson study cycle. However, facilitators' focus on active teacher participation was not significantly associated with teacher participation in an effective inquiry process. Overall, significant proportions of the variations in teacher participation in an effective inquiry process and perceived knowledge growth were explained by the independent variables with high R^2 values of .64 and .53 respectively.

Fig. 3 shows that when the outcome is self-efficacy, in addition to the same relationships between design features and an effective inquiry process, two statistically significant direct paths were identified. Facilitators' focus on student thinking and perceived material quality were both significantly and positively associated with self-efficacy. These relationships indicate the importance of both a facilitator's focus on student thinking and a selection of useful materials for increasing self-efficacy of teachers. 47% of the variation in self-efficacy was explained by design features and teacher participation in an effective inquiry process of lesson study.

In Fig. 4, no significant direct effect was observed between design features and expectation on students, beyond indirect effects through the effective inquiry process of lesson study. However, the relationship between teacher participation in an effective inquiry process and expectation was statistically significant with a large standardized coefficient of .51. When teachers participated in an effective inquiry process, teachers are more likely to report that their expectation of students increased. Through a careful planning of a research lesson and collective observation and discussion of students' mathematical thinking, teachers may have realized what their students are capable of and changed their beliefs about students' potential as mathematical thinkers. 26% of the variation in the perceived change in expectation was explained by teacher participation in an effective inquiry process.

Table 4 summarizes the indirect effect, direct effect, and total effect (sum of indirect and direct effects) for each design feature to compare the relationships between design features and three teacher learning outcomes. Our path analysis showed that facilitators' focus on student thinking has the largest total effect overall, followed by material quality and duration. Facilitators' focus on active teacher participation was not significantly associated with teacher participation in an effective inquiry process, thus the limited effect on teacher learning outcomes.

5. Discussion and conclusions

This study examined how key design features of mathematics lesson study are associated with teacher learning outcomes mediated through teacher participation in an effective inquiry process. Before discussing the findings, it is important to note the limitations. First, survey data were collected from only 87 teachers in 24 groups in Florida. As no sampling frame—a list of all teachers who practiced mathematics lesson study in Florida—exists, the survey relied on the reports of the districts and schools to compile the list. From this list, a high response rate was achieved (79%), yet the data are not generalizable as there are many other teachers in the target group who did not participate in the survey, either because their districts did not allow the researchers to conduct a survey or the districts were not aware of teacher engagement in mathematics lesson study.

Second, although path analysis is designed to test the causal model identified in our conceptual model, it is important to clarify that no causal relationship can be established from cross-sectional survey data collected at one time point. The survey items were carefully developed to capture changes after the lesson study cycle, yet the data relied on teachers' perceptions of changes, instead of actual changes in teachers' beliefs using longitudinal survey data.

Despite these limitations, the study produced findings with important implications for policy and practice. First, we observed major variations in the design features as well as teacher participation in an effective inquiry process. Even though lesson study offers structures with four specific stages, the time span ranged from one day to 118 days and the amount ranged from 2 hrs to 23 hrs. These variations may stem from various sources, such as the time and resources and the way lesson study was introduced to teachers. Our district survey data showed that lesson study was introduced to Florida teachers as a short-term, simplified process without an inquiry process of studying curriculum, teaching, and student learning (Akiba & Wilkinson, 2016). At the same time, there are many lesson study groups in Florida funded by various researchers who promoted a continuous, long-term learning process. The differences in how lesson study was introduced to teachers and the availability of funding may explain the variation in the time span and amount of lesson study.

We also observed major variations in facilitator orientation in terms of foci on student thinking and active teacher participation. The perceived quality of materials also varied across teachers. These variations are natural results of a teacher-driven process, which may reflect the differences in the experience and knowledge of the teacher leaders who facilitate lesson study, as well as their access to high quality materials to deepen teacher learning.

Second, path analysis results showed that, among the four design features, facilitator focus on student thinking was most strongly associated with perceived changes in knowledge, self-efficacy, and expectation. Previous studies have identified the important role of facilitators in leading in-depth discussions of various student solutions and anticipated student responses, an analysis of students' mathematical thinking, and a review of students' learning progressions (Borko et al., 2014; Elliott et al., 2009; Kazemi et al., 2011; Koellner et al., 2011). Effective facilitation focused on student thinking requires facilitators' knowledge about the topic of focus and students' diverse mathematical reasoning and strategies along learning progressions. Our analysis indicates that these facilitators can not only lead an effective inquiry process, but also could directly influence teachers' perception of knowledge

Table 4
Indirect, direct, and total effects in path models.

Design Features	Outcomes	Indirect Effect via Effective Inquiry Process	Direct Effect	Total Effect
Duration	Knowledge Growth	.09	N/A	.09
	Self-Efficacy	.05	N/A	.05
	Expectation	.10	N/A	.10
FO: Student Thinking	Knowledge Growth	.19	.33	.52
	Self-Efficacy	.12	.21	.33
	Expectation	.22	N/A	.22
FO: Active Teacher Participation	Knowledge Growth	.05	N/A	.05
	Self-Efficacy	.03	N/A	.03
	Expectation	.06	N/A	.06
Material Quality	Knowledge Growth	.11	N/A	.11
	Self-Efficacy	.06	.32	.38
	Expectation	.12	N/A	.12

growth and self-efficacy.

An unexpected finding emerged from the lack of a statistically significant relationship between facilitators' focus on active teacher participation and teacher participation in an effective inquiry process of lesson study. Active learning—one of the important characteristics of effective professional development (Desimone, 2009; Desimone et al., 2002; Loucks-Horsley et al., 1998; Wilson & Berne, 1999)—is generally assumed to occur when teachers actively engage in a learning process through discussions and reflections. Yet the facilitators' focus on actively engaging in discussions was not associated with teacher participation in an effective inquiry process or any of the teacher learning outcomes.

Previous qualitative studies that examined the nature of teacher discourses in TLCs may offer some insight into this lack of a statistically significant relationship. Horn and Little (2010) compared two teacher work groups working toward a shared goal and showed how one group provided richer learning opportunities because of their in-depth discussion of student thinking and teaching based on vivid examples of classroom practices. We expected that such in-depth discussions would occur naturally in lesson study because of the collective development and observation of a research lesson. However, this may not have occurred if the facilitator did not guide the group discourses to carefully analyze and interpret what was observed in the research lesson, paying close attention to the student thinking and understanding behind student work or small group and whole group discussions in the classroom. Teachers need to experience a cognitive conflict or dissonance in order to change their beliefs about teaching and student learning (Clarke & Hollingsworth, 2002; Opfer & Pedder, 2011) and simply ensuring that all teachers actively participate in discussions may not change and might possibly even enforce existing traditional views about teaching and student learning (McLaughlin & Talbert, 2001).

Our case study of lesson study groups (Murata, Akiba, Howard, Kuleshova, & Fabrega, 2017) has also produced a consistent finding. A comparison of two lesson study groups revealed that despite the commonality in the their commitment to improving student learning led by an experienced teacher leader who valued active participation of each member in group dialogues, one group's discussion focused on instructional approaches to ensure that students achieve the correct answer, while the other group's discussion focused on understanding students' conceptual thinking behind their mathematical work and developing instructional approaches to reveal various student thinking to deepen their understanding.

It is important to note, however, that the lack of a statistically significant relationship between the facilitator's focus on active teacher participation and teacher learning outcomes does not mean that active learning is not important. Since facilitator focus on active teacher learning is strongly correlated with the facilitator focus on student thinking ($r = .78$), these two factors likely co-exist in most cases of lesson study facilitation. The lack of a statistically significant relationship indicates that a sole focus on active teacher participation without a focus on student thinking will not likely lead to teacher engagement in an effective inquiry process and positive learning outcomes.

Finally, the material quality and duration of lesson study were found to be significantly and positively associated with teacher participation in an effective inquiry process, which in turn was significantly associated with perceived knowledge growth, self-efficacy, and expectation. The importance of resource materials is consistent with prior studies that demonstrated that resource-supported lesson study groups improved knowledge and student learning (Lewis & Perry, 2014, 2017; Perry & Lewis, 2009). The duration of lesson study—a combination of a time span and number of contact hours—was also significantly associated with teacher participation in an effective inquiry process. This shows that a short-term process of lesson study will not likely lead to positive learning outcomes.

These findings have important implications for district, school, and teacher leaders who support a teacher-driven, collaborative, inquiry-based learning process of lesson study, or any other collaboration-based professional development or teacher leaning communities. The strong correlations among these four design features show that these features likely co-exist to form an important condition that is associated with an effective inquiry process of lesson study, which is also significantly associated with perceived positive changes in teacher knowledge, self-efficacy, and expectation. Increasing teacher knowledge, self-efficacy, and expectation for students is especially important considering that the ambitious mathematics instruction envisioned in current reforms requires teachers' use of cognitively demanding tasks (NCTM, 2014; Stein & Smith, 1998). The finding that more than half the variation in teacher participation in an effective inquiry process was explained by these four design features ($R^2 = .64$) shows that these are indeed promising conditions that could be considered for promoting an effective practice of lesson study.

It is important to point out, however, that each of these design features requires a significant level of investment from the district or school. Among our survey participants, the groups that could engage in a long-term process were often supported by funded projects, which were not available to most groups. Most districts and schools do not have a comparable level of funding to cover substitutes for multiple days and teacher payments to support a long-term process of lesson study. This is especially the case when a district supports multiple professional development programs and lesson study is only one of many options. Prioritizing a small number of professional development offerings and embedding lesson study into regular school professional development schedules (e.g., early release days, professional development days, PLC time) may address the issue of funding to support a long-term process of lesson study.

Supporting the development of lesson study facilitators and providing access to high quality materials also requires a great amount of time and resources. The study shows that an effective facilitation of teachers' study and discussion of student thinking is a promising area for future investment. This may require developing teacher leaders' content and pedagogical content knowledge as a foundation. Teacher leaders also need to select a cognitively demanding task for eliciting various students' ideas, which serve as important starting points for a discussion of student thinking. Development of high quality materials for lesson study is also important and requires access to research-based knowledge. A partnership with researchers and professional developers who can work with district instructional leaders and teacher leaders may help districts support lesson study facilitators and the development of high quality materials.

TLCs have been touted as a best practice for promoting teacher learning for many years, but this study revealed that the link between various aspects of collaborative learning processes in TLCs such as lesson study and teacher learning may not be straightforward. Our data along with previous studies seem to support that simply promoting active engagement in TLCs without a deliberate focus on student thinking is not likely to influence teachers' beliefs about teaching and student learning. Investing in important design features of TLCs likely enhances the potential benefits of a collaborative, inquiry-based learning process in TLCs that supports teacher learning. At the same time, more studies are needed to identify the design features of teacher-driven, collaborative, inquiry-based learning activities in TLCs that influence the nature of teacher discourses in ways that enhance learning opportunities. Future studies could examine variation in the quality of teacher discourses with different design features based on video-recorded meeting data and teacher interviews to understand their learning experiences and changes in their beliefs about teaching and student learning. Specifically, the role of facilitators in guiding teacher discourses on student thinking and instruction could be further explored by analyzing the detailed nature of interactions between facilitators and teachers in each stage of lesson study.

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Appendix. Major Variables, Coding, and Reliability Indices

Domain	Variables	Survey Questions	Coding
Design Features	Duration	Mean of standardized time span (number of days) and amount (number of hours) computed based on the submitted lesson study schedule.	
	FO: Student Thinking (Mean of 4 items, $\alpha = .92$)	To what extent do you agree or disagree with each of the following statements about the facilitator of your lesson study group? *My lesson study facilitator …* a. guided an in-depth discussion of various student solutions to a math problem. b. engaged us in analyzing students' thinking in mathematics. c. engaged us in reviewing how student learning progresses across grade levels. d. guided a discussion of anticipated student responses representing common patterns of children's thinking.	1 = Strongly disagree 2 = Disagree 3 = Slightly disagree 4 = Slightly agree 5 = Agree 6 = Strongly agree
	FO: Active T. Participation (Mean of 3 items, $\alpha = .83$)	*My lesson study facilitator …* a. encouraged each group member to share our prior experience teaching the mathematics topic. b. listened carefully and valued what each member had to say. c. made sure that all members contributed to the discussion and lesson planning.	1 = Strongly disagree 2 = Disagree 3 = Slightly disagree 4 = Slightly agree 5 = Agree 6 = Strongly agree
	Material Quality (Mean of 9 items, $\alpha = .92$)	How useful were the materials your group used for the following activities? a. Understanding the process of lesson study b. Understanding how the Mathematics Florida Standards (MAFS) or Common Core State Standards in Mathematics (CCSSM) addresses the chosen topic or unit c. Understanding how mathematics content relevant to the chosen topic builds across the grade levels d. Deepening the content knowledge of the chosen topic among lesson study group members e. Exploring various instructional approaches for the chosen topic f. Learning various approaches for a student-centered instruction or problem solving on the chosen topic g. Developing instructional materials (e.g. manipulatives, worksheets) to facilitate students' conceptual understanding h. Anticipating our students' possible mathematical responses to a certain question or activity i. Interpreting student responses and work to a certain question or activity	1 = Not useful at all (or no material used) 2 = Somewhat useful 3 = Useful 4 = Very useful
Teacher Participation in an Effective Inquiry Process	Effective Inquiry Process (Mean of 18 items, $\alpha = .93$)	The following statements describe your activities for studying the chosen topic/unit and developing a lesson plan. To what extent does each of the following statements apply to your lesson study group's activities? a. We shared our past experiences with teaching this topic/unit to students. b. We discussed our students' current level of understanding of this topic/unit. c. We discussed how student learning of this math topic/unit progresses across the grade levels. d. We developed or chose a math problem-solving task that is motivating and meaningful to our students. e. We developed or chose a problem-solving task that will reveal students' common misconceptions. f. We developed or chose a math problem-solving task that allows students to deepen their understanding through comparing multiple solutions shared by their classmates. g. We developed a sequence of questions and activities that will support students to achieve the learning goal. h. We solved a problem-solving task by ourselves to anticipate students' various solutions. i. We developed or chose a lesson in which students can take ownership of their learning through collectively engaging in problem-solving tasks. j. We discussed and decided the data we need to gather in order to assess whether and how students achieved the learning goal. k. We developed key questions that guide our data collection (e.g. How did the posed problem help students deepen their understanding? How did students' use of a manipulative guide their solutions?)	1 = Not at all 2 = To small extent 3 = To medium extent 4 = To large extent
		The following statements describe the debriefing (discussion) of the research lesson. To what extent does each of the following statements apply to your lesson study group's	1 = Not at all 2 = To small extent

(*continued*)

Domain	Variables	Survey Questions	Coding
		activities? a. The instructor shared his/her reflection on how the lesson went and what he or she learned. b. The lesson study group explained the goal and the learning process for developing this research lesson. c. The lesson study group members presented data as evidence of student learning (e.g. student work, student questions, narrative record of student activities, student solutions shared on a chart paper or a white board). d. The presented data were organized around our key questions for data collection. e. The discussion focused on student learning and how specific elements of lesson design promoted it. f. We discussed how to improve the lesson for future teaching. g. The facilitator kept the discussion focused on the effectiveness of the lesson for achieving the student learning goal and how to improve the lesson.	3 = To medium extent 4 = To large extent
Teacher Learning Outcomes	Knowledge Growth (Mean of 9 items, $\alpha = .98$)	To what extent do you agree or disagree with the following statements about the changes in <u>your knowledge</u> that have occurred <u>a result of participating in this mathematics lesson study</u>? a. I have a better understanding of the mathematics content our group focused on. b. I gained knowledge on various instructional approaches to teach the mathematics content. c. I know more about common student understanding and misconceptions in our chosen mathematics unit or topic. d. I gained knowledge on how student learning of the chosen topic or unit progresses over time. e. I know more about how to develop a student-centered lesson or problem-solving tasks. f. I know more about how to use various resources to develop a lesson plan. g. I know more about how to observe and analyze student thinking process. h. I know more about how to discuss student data we gathered during a research lesson as evidence of student learning. i. I have a better understanding of how to facilitate the learning of students with diverse learning styles and needs.	1 = Strongly disagree 2 = Disagree 3 = Slightly disagree 4 = Slightly agree 5 = Agree 6 = Strongly agree
	Self-Efficacy (Mean of 4 items, $\alpha = .86$)	To what extent do you agree or disagree with the following statements about the changes in <u>your beliefs</u> as <u>a result of participating in this mathematics lesson study</u>? a. I realized that I can improve student learning by changing my teaching practice. b. I believe engaging in a continuous investigation of student thinking and understanding will improve my teaching. c. I feel that my knowledge and teaching will continue to improve by experimenting with various instructional approaches through lesson study. d. I believe I can teach my students more effectively if I continue to engage in lesson study.	1 = Strongly disagree 2 = Disagree 3 = Slightly disagree 4 = Slightly agree 5 = Agree 6 = Strongly agree
	Expectation (Mean of 3 items, $\alpha = .80$)	To what extent do you agree or disagree with the following statements about the changes in <u>your beliefs</u> as <u>a result of participating in this mathematics lesson study</u>? a. I realized that my students are capable of tackling a challenging mathematics problem. b. I believe that students learn better when we hold them to a higher expectation. c. I learned the value of giving a challenging problem in order to show what my students are capable of.	1 = Strongly disagree 2 = Disagree 3 = Slightly disagree 4 = Slightly agree 5 = Agree 6 = Strongly agree

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