Improving core instructional practice in mathematics teaching through lesson study

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Abstract

Purpose – The purpose of this paper is to examine how teachers improve core instructional practices in teaching mathematics for problem solving through lesson study (LS). The core practices included launching a task, implementing a task, and orchestrating students' solutions.

Design/methodology/approach – This study adopted multiple case study and survey methodologies. Each of three LS groups developed a research lesson on problem solving in algebra through Chinese LS, which includes collaborative planning and repeated teachings/debriefings of the research lesson with support from experts. The data collected included lesson plans, videotaped research lessons and debriefing meetings, and an end-of-project survey. Case studies supported by survey data were utilized to describe how research lessons were improved and what teachers learned from LS.

Findings – A fine-grained analysis of the data revealed that the participants improved their strategies for teaching for problem solving, which included effectively launching tasks, strategically implementing tasks, and productively orchestrating students' solutions to the tasks. Further, analyses revealed that the feedback from experts during debriefing meetings played crucial roles in making these changes. Moreover, participants learned how to implement these core instructional practices and changed their views about students' learning.

Originality/value – The study uncovers the mechanisms about how teachers improve teaching and their expertise in teaching through Chinese LS. The importance of the dynamic between repeated teaching and immediate feedback from knowledgeable others is highlighted.

Keywords Deliberate practice, Chinese lesson study, Core instructional practice, Enactments and reflections

Paper type Research paper

Introduction

Teaching problem solving has been recommended in mathematics curriculum reforms for decades (National Council of Teachers of Mathematics (NCTM), 1989, 2000, 2014; Schoen and Charles, 2003). It includes core instructional practices such as launching tasks (Jackson *et al.*, 2012), implementing tasks (Stein *et al.*, 2009), and orchestrating students' solutions (Smith and Stein, 2011). Implementing these core instructional practices, however, is challenging (Gewertz, 2013; Takahashi and McDougal, 2014). Lesson study (LS) can support teachers' changes to their instructional practices (Takahashi and McDougal, 2014) and promote teachers' development of instructional expertise (Huang and Han, 2015). This study explored improving teachers' capacity with core instructional practices associated with teaching problem solving through LS. Specifically, the research questions were:

RQ1. How did the teacher participants improve the research lesson, which focused on teaching for problem solving (TfPS), through LS?

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RQ2. How did interactions between enactments and reflections on the research lesson contribute to the improvement of the research lesson?

RQ3. What did teacher participants learn from participating in the LS?

Theoretical framework

This study was based on three interconnected theoretical lenses. Each of these theoretical lenses is described below.

Core instructional practices

Teacher learning emphasizes enactments of practice (Grossman and McDonald, 2008) that focus on "specifying teaching practices that entail knowledge and doing" (McDonald *et al.*, 2013, p. 378). Thus, identifying core practices (Ball *et al.*, 2009; Hatch and Grossman, 2009; McDonald *et al.*, 2013) has gained interest amongst teacher educators. Although researchers use different terms, it is agreed that the core practices should be research-based, having the potential for teachers to learn about students and teaching. In particular, the recently released "Principles to actions" (NCTM, 2014) described eight research-based effective mathematics teaching practices. Although these practices provide a useful frame for describing core instructional practices, teachers face challenges in implementing them in their classrooms.

In this study, we investigated the core instructional practices, which are closely related to TfPS. TfPS features students applying learned knowledge to solve contextual problems and deepen their understanding of the learned knowledge. Implementing TfPS involves three core instructional practices: launching cognitively demanding mathematical tasks and engaging students in rigorous mathematical content (Jackson *et al.*, 2012; Weiss and Pasley, 2004); maintaining the cognitive demand of tasks during implementation and providing opportunities for students to engage in high-level thinking and reasoning (Stein *et al.*, 2009); and providing opportunities for students to discuss their reasoning and solutions (Boston, 2012; Smith and Stein, 2011). By focusing on a specific algebra topic (i.e. function and graph), this research explored implementation of these core instructional practices.

Deliberate practice

Cognitive scientists suggest that participation in special activities is an important factor for continued improvement and attainment of expert performance (Ericsson, 2008; Ericsson *et al.*, 1993). Ericsson and colleagues (1993) defined deliberate practice as special activities developed for and repeatedly pursued by individuals with feedback from experts. Engagement in deliberate practice means that one is given a task with a well-defined goal, motivated to improve, and provided with feedback and ample opportunities for repetition, resulting in gradual refinements in performance (Ericsson, 2008; Ericsson *et al.*, 1993). Deliberate practice has four characteristics (Bronkhorst *et al.*, 2013; Ericsson *et al.*, 1993; Gog *et al.*, 2005). First, the practice is designed for self-improvement. Proper sequencing of challenging tasks should be set with the support from knowledgeable others (i.e. teachers, coaches, and trainers). Second, the practice is repeated to enable successive improvement and refinement. Third, the repetitive practice is followed by immediate feedback concerning different aspects that underlie the practice. Fourth, the practice requires significant effort and concentration.

Chinese LS

LS, a practice-focused, collaborative professional development model, has spread globally (Huang and Shimizu, 2016; Lewis and Lee, 2017) and demonstrated its effects in improving teaching and student learning (Lewis and Perry, 2017; Cheung and Wong, 2014) and promoting teachers' growth in implementing reform-oriented curriculum (Hart *et al.*, 2011; Lee and Lo, 2013; Lewis *et al.*, 2009; Lewis, 2016). Although similar to Japanese LS structurally (Lewis *et al.*, 2009), Chinese LS regards repeated teaching of the research lesson and knowledgeable others' input as necessary components of a LS, rather than optional (Huang and Han, 2015). In this way, Chinese LS embodies characteristics of deliberate practice.

Within a context of Chinese LS, Han and Paine (2010) found that improving teaching of mathematics as deliberate practice "gave the teachers an opportunity to refine their instruction in three core aspects that included designing appropriate mathematical tasks for students, teaching the difficult mathematical idea, and using mathematically, pedagogically appropriate language" (p. 519). Furthermore, Huang *et al.* (2013) argued that, due to the commonalities, Chinese LS is a type of deliberate practice. Thus, Chinese LS enables teachers to make continued improvements in teaching and develop core instructional practices.

A framework for the current study

From the literature (Han and Paine, 2010; Huang and Han, 2015), Chinese LS includes the major features of deliberate practice: well-defined instructional goals, repeated teaching experiments, immediate expert feedback, and opportunities for reflection and revision. Similarly, Lampert *et al.* (2011) highlighted that repeated enactments of lessons are needed to develop teachers' ability to enact core instructional practices. Thus, although a typical cycle of LS involves setting research goals, collaboratively planning a research lesson, delivering and observing the research lesson, and debriefing on the research lesson, this current study emphasized repeated enactments, reflections, and knowledgeable others' input in addition to the typical cycle, as these are key components within the theory of deliberate practice. Therefore, this study aimed to examine improvement of selected core instructional practices through a Chinese LS approach.

Methodology

Research context

This study occurred within a professional development project in a suburban school district located outside a large city in a southeastern state in the USA. In total, 15 high school mathematics teachers from six schools participated. The purpose was to improve teachers' capacities in implementing newly adopted curriculum standards (Common Core State Standards Initiative (CCSSI), 2010) through LS. The overarching research question was to examine what and how the participating teachers learned from the project, and school-based LS in particular. Two knowledgeable others (a university mathematics educator and the district's mathematics specialist) led workshops and facilitated the school-based LSs. The project included three phases. Each phase is described below.

Pre-LS workshops. Two Saturday meetings occurred prior to conducting the LSs. The first meeting enriched participants' understandings of the mathematics teaching practices (NCTM, 2014) and their alignment with their curriculum (CCSSI, 2010). Attention was given to supporting productive struggle, which provides students with "opportunities for delving more deeply into understanding the mathematical structure of problems and relationships among mathematical ideas, instead of simply seeking correct solutions" (NCTM, 2014, p. 48). The second meeting focused on how to conduct a LS (Lewis and Hurd, 2011). Participants formed LS groups (three or four teachers within a school, if possible) and identified tentative goals for the research lesson.

Five LS groups were formed. Group A included four participants from a high school classified as high need. Groups B (three participants) and C (three participants) were from an average high school. Group D (three participants) included teachers from a high-achieving high school. Group E included three participants from different schools.

School-based LS. After the second workshop, each LS group selected a topic, determined which participant would teach the research lesson, and collaboratively developed a lesson plan. Groups submitted their lesson plans to the experts ten days in advance of teaching. Experts sent written feedback to groups five days before teaching the lessons.

On the day of teaching the research lesson for each group, the experts visited the school and observed the group's activities, which included: teaching/observing the first research lesson in the morning; first debriefing and revising the lesson plan immediately after the first teaching; re-teaching the research lesson in another classroom at the same grade in the afternoon; and second debriefing immediately after the second teaching. Participants in each group participated in the entire process.

Post-LS sharing. One Saturday meeting focused on participants sharing their LS experiences. Group presentations included: the selected task; implementation description; the research lesson and evidence of student learning; major improvement(s) to the research lessons; major benefits; and impact(s) on daily teaching.

Participants

Since this research focused on core instructional practices with respect to TfPS in Algebra I, Groups D (pre-calculus content) and E (elementary mathematics content) were excluded from the case study analyses. Table I contains the background information of remaining participants. Participants represented a typical teacher cohort regarding their educational background and teaching experience.

Data sources

Data sources included: lesson plans; videotaped research lessons and post-lesson meetings; and student-generated lesson artifacts. Also, to understand what participants learned from the project, participants completed a five-point Likert-scale survey and an open-ended survey (see Appendix 1).

Data analyses

To answer the first research question, studio-code was used to code evidence of the core practices: launching, implementing, and orchestrating. Based on literature and our previous studies, we created a framework for examining these core instructional practices (see Table II).

Based on this framework, the major changes between the two research lessons of each group were identified and triangulated with the transcriptions of debriefing sessions and survey responses.

Table I. Background information of the participant

LS group	Teacher	Education background	Years of teaching
A	TA1	BA in communications/Master in math education	7
	TA2	BA and MS in math education	7
	TA3	BS in mathematics	1
	TA4	BS in engineering	1
B	TB1	BS in mathematics	2
	TB2	BA in special education	5
	TB3	BA in sport management	4
C	TC1	BS in mathematics	3
	TC2	BS in mathematics	7
	TC2	BA in special education	2

Core instructional activities	Component of each practice	Examples
Launching a task	1. Discuss the key contextual features	Renting fee, cost per hour, cost in total
	2. Discuss the key mathematical ideas	*Y*-intercept, slope, *x*-axis, *y*-axis, increase, decrease, equation, function
	3. Develop common language to describe the key features	Making sure students understand the connections between contextual terms and mathematical concepts
	4. Maintain the cognitive demand	No hints about any strategies for solving the tasks
Implementing a task	1. Individual work	Giving clear instructions for what student need to do individually
	2. Group discussion	Stop and walk away: asking assessing and advancing questions with limited leading questions
	3. Preparation for sharing group work	Avoiding one dominating the collaborative work; each student takes his/her accountability
Orchestrating student work	1. Anticipating	Anticipating student solutions to cognitively demanding mathematical tasks
	2. Monitoring	Monitoring students' responses to the tasks during the group activity
	3. Selecting	Selecting particular students to present their mathematical solutions during the sharing period
	4. Sequencing	Sequencing the student answers that will be discussed
	5. Connecting	Helping the class make mathematical connections between different answers and key ideas

Table II. Description of components of core instructional activities for TfPS

For the second research question, we identified themes that emerged from the debriefing sessions through analyzing the transcript line by line, and the alignment between the identified key points and changed practice in the second teaching were examined. To address the third question, we analyzed survey data both descriptively and qualitatively. Also, we analyzed participants' individual journals and open-ended surveys, with five themes regarding participants' learning emerging.

The results are presented in two sections. First, a descriptive case is offered of Group C. Due to space limitations, we are only able to describe one case in detail. We chose to feature Group C because the group's school represented an average-level school regarding academic performance and economic background with a very diverse student population. Also, the members of Group C represented a typical combination of teachers in the project regarding academic background and teaching experience (see Table I). Through the description of Group C's experience, we offer a means to better understanding the summary of results in the second section.

Limitations

This study has certain limitations such as no direct assessment of students' learning outcomes and no attempt to address sustainability of teacher learning beyond the short-term LS. Yet, the detailed description of changes in the research lessons and debriefings from multiple groups of LS advances the development of understanding why Chinese LS can promote teacher learning at a larger scale.

Results: Group C

Research lesson

Group C developed their research lesson based on the Surfboard Task (University of Pittsburgh, 2013). The lesson goals involved "developing understanding of creating functions and how the context affects possible values for the functions." The specific mathematical foci were: understanding slope as rate of change; connecting each part of a linear equation to the graph and context; and understanding the domain of a function. The following sections present a description of the first teaching/debriefing and the second teaching/debriefing. Attention is given to the changes in the research lesson within the three core instructional practices of TfPS.

First teaching. The research lesson followed the lesson structure emphasized at Group C's school. To launch the task, the instructor (TC1) directed the students to read the task and share their observations. Observations included: the *y*-axis increases by ten dollars; the *y*-axis represents the cost in dollars; the graph has positive slope; and the cost of renting a surfboard is different for different amounts of time.

Next, TC1 proceeded to implement the task in two phases. First, TC1 provided students with three minutes of independent think time. She directed them to "begin to think about possible ways to answer each question in the task and write down your answers to each question on your paper." As students worked, TC1 circulated the classroom, discussing the task with what appeared to be a goal of leading students to the correct answer(s). Second, TC1 directed the students to work in their groups to share their solutions and collaboratively prepare a poster. She assigned each group member a number, which corresponded to the task question to which that student was responsible for recording on the poster. She cautioned, "Every [group] member must be prepared to present any part of your group's answers with the class." Poster preparation lasted for approximately 15 minutes. During this time, TC1 circulated the room, asking leading questions and lingering with each group to help the students find correct answers.

In orchestrating student's solutions, TC1 gave each group three minutes to present the work on their posters. She attempted to generate discussion of solutions, asking questions regarding the use of equations vs. graphs. The discussion was limited, however, as each group presented their correct answers, with little comparison of methods. The students appeared to struggle, though, in terms of understanding the domain of the function within the context of the problem. Following the presentations, students completed an exit ticket, in which they considered how the graph and equation might change if the cost per hour for renting the surfboard changed.

Debriefing. To begin, participants indicated that the lesson's mathematical goals were met. Further, they felt that the questioning during the launch activity was appropriate for engaging the students in the task. However, participants were concerned about the lack of variety in solutions and/or solution processes, which did not lead to productive discussions. In this way, their concerns focused on the lesson's implement and orchestrate practices.

In response, the experts reminded participants of the role of productive struggle in learning:

> The fact that they struggled with [domain in the problem context] a little bit is not a bad thing, that's a good thing. It's a newer concept for them; they're kind of working through it. They probably gained more than you standing up there and saying this is domain – this is range.

The experts offered two suggestions aimed at maintaining the cognitive demand of the task within the implementation practice. First, "teachers should not intervene with students' thinking; [rather] let students explore their own thinking and strategies." To support this idea, the experts recommended having students collaboratively discuss their solutions to the task prior to poster preparation, rather than assigning each group member a focus question. Second, the experts emphasized that it is not necessary for all students to get the correct answer. Therefore, when circulating during group work, the teacher should ask "questions to the students and then walk away and let the students discuss."

The experts reminded participants that by asking fewer leading questions, the result would likely be more variety within student work, which would address some of the concerns related to the orchestrate practice. Further, one expert stated:

> Identifying mistakes/struggles observed during group work, having the students compare/contrast group work, asking students to explain how they got their solutions, then you can ask the class if anyone solved it a different way. You do not need to share every student's work. The focus needs to be on different solutions and different ways of solving.

Here, the expert connected the teacher's work during the implementation practice to the orchestrate practice. In addition, the suggestion was offered to not have every group share all work, but rather to be more strategic regarding what is shared and how it is discussed. Based on these discussions and recommendations, participants revised the research lesson.

Second teaching. The organization of the revised research lesson matched the earlier version. Salient changes were present, though, that related to ways of facilitating the group activity and orchestrating the discussion of the students' work.

TC1 launched the task by asking students to read the task and share their observations, which mirrored those from the previous teaching. To implement the task, TC1 directed students to utilize their independent think time to work on the task. Although TC1 circulated the room, there was little interaction with the students during this phase. Then, she directed the students to work collaboratively as they discussed the task and prepared a poster of their solution(s). During this second phase, TC1 stopped at each group to ask advancing and assessing questions. Then, she walked away, without necessarily waiting to hear a response, and continued monitoring students' progress. Midway through group exploration, TC1 reminded students that they were charged with preparing a poster collaboratively so as to share their ideas. Students generated a variety of ways for solving the task and developed different solutions, including errors.

To begin orchestrating students' solutions, TC1 directed students to tape their posters at the front of the room. Then, she directed the students to compare the different solutions. Students generated correct solutions for questions one and two, although some groups utilized an equation and others a graph. TC1 used this opportunity to query students regarding the relationship between the equation and the graph as well as the differences between these two solutions. When students reported that the solution methods were the same, TC1 posed a new scenario that facilitated students' recognition of the efficiency afforded in using the equation. For the third question, the students produced three different solutions. As students discussed these, TC1 noted that class time would soon end without resolution of the third question. Therefore, students completed an exit ticket regarding the reasonableness of their preferred answer(s).

Second debriefing. Group C shared reactions to the lesson, giving attention to how the changes influenced the lesson outcomes. In terms of implementing the task, the participants noted that TC1 spent less time interacting with students. TC1 noted, "[During the first lesson], it was almost like – what am I thinking? And then, they are writing down what I'm thinking." She described how she circulated the class and watched the students working during the second lesson. The participants indicated that spending less time with each group led to more variety in the answers. In addition, the participants noted that this variety led to more meaningful discussions as TC1 orchestrated students' solutions. Therefore, the changes in the research lesson appropriately addressed the previously expressed concerns.

Further reflection led to discussing the learning outcomes. Participants stated that more learning occurred in the second lesson for the students and the instructor. For students, the revised lesson better supported learning through the use of multiple representations and solution methods. For the instructor, she learned more about how the students were thinking in relation to the task and its mathematical ideas. Participants expressed that these learning opportunities were a result of the lesson changes.

Despite the enthusiasm generated by the lesson, participants expressed some concern regarding orchestrating students' solutions. Participants noted that in the first teaching there was minimal discussion because the answers were similar. In the second teaching, however, the students appeared to "get lost in their discussion," which resulted from a lack of experience in dealing with students' errors. Participants desired a balance between these two extremes, which led to a discussion focusing on monitoring, selecting, and sequencing solutions.

Perceptions of learning

Group C reflected on their experiences in their individual journals. An analysis of these writings revealed three themes, which are described below.

Student learning. Two of the participants (TC1 and TC2) reflected on supporting student learning. Both participants described the need to explore/discuss students' ideas. TC1 wrote, "Teacher questioning should be less funneling because the students work all turned out very similar (which is not necessarily a bad thing) but we want to see the student's thinking – not the teacher's thinking." Here, TC1 noted the role of questioning, which can lead students to the teacher's way of thinking (e.g. first teaching) or provide support for students generating their own ideas (e.g. second teaching). When students generate their own ideas, the result is typically a variety of solutions and solution processes, which were the focus of TC2's reflection. She wrote, "I was pleased with the variety of student work that was generated from the changes in the lesson. This led to a lively discussion of their thinking, which could improve future lessons." Discussions of the multiple representations and solutions will support student learning.

Improving teaching. Participants also addressed actions that support TfPS. TC1 and TC3 recognized that in orchestrating solutions, it is not necessary for each group to present all of their work. Rather, the teacher should be strategic in how this work is shared. TC3 wrote:

> Instead of focusing on each individual question with each group, spend more time picking out work from two different groups that reached the answer using a different method. This allows students to see that there are different methods to answering the question.

In addition, TC1 commented on including mistakes:

> Allow the students to struggle, make mistakes and learn from their mistakes. Spend time letting the students compare each other's work and see the value in different methods while still making sure they understand the goal of the lesson and the best route for achieving that goal.

Both of these participants identified actions that teachers should take when implementing TfPS.

Long-term impact. All three participants reflected on the long-term influence of the LS experience on their professional development. TC1 wrote, "I saw a significant difference between the two lessons based on my questioning strategies. Getting input from other teachers is very beneficial […] It impacted the way I will teach my lessons from now on." Here, TC1 noted the influence of the experience on her questioning. In contrast, TC2 focused on productive struggle:

> It has made me more aware of the changes I need to make in my classroom. I appreciate the concept of productive struggle and how it can lead to deeper understanding. I have always been too quick to provide a solution for my students, which prevents their concept development.

TC3 also commented on questioning and productive struggle. In addition, she noted her tendency to give students too much guidance. "As a teacher I always want to guide them to the right answer too quickly. Allowing students to really think about what is being asked and how to answer the question is an effective teaching strategy." Participants identified the influence of the experience on their future teaching practices.

Summary of results for three groups

Major changes

The main themes that emerged from the analyses of post-lesson debriefing meetings and major changes to the research lessons are identified in Table III. Group A's debriefing discussion focused on making sense of the contextual problem, maintaining the cognitive demand of the task, and orchestrating the student work. In contrast, Group B's discussion focused on organizing the group activity and orchestrating student work. Group C's discussion focused on maintaining cognitive demand of the task, organizing group activity, and orchestrating student work. Table III shows that discussions in different groups were related to all three aspects with different foci. Orchestrating student's work was the common theme discussed.

Improvements to the research lessons (see Table III) in the three groups were made in all three TfPS practices. To better understand these improvements, the changes are summarized in Table IV.

Salient changes across groups suggested that all groups made substantial changes in organizing the lesson toward a focus on building on individual work and negotiating shared solutions within a group, as well as orchestrating student work toward building connections of mathematical ideas through comparing/contrasting solutions. Table III demonstrates the alignment of the key points from debriefing meetings and the changes made in the second teachings. All research lessons were improved by implementing appropriate strategies for orchestrating work (selecting, sequencing, comparing, and connecting). Two of the three research lessons were improved with regard to launching tasks, focusing on making sense of the tasks and maintaining cognitive demand of the task. Two of the three research

		Occurrence of themes or key points					
		LS A		LS B		LS C	
Core instructional activities	Component of each practice	Debrief	Second teaching	Debrief	Second teaching	Debrief	Second teaching
Launching a task	1. Discuss the key contextual features	X	X	X			
	2. Discuss the key mathematical ideas	X	X	X			
	3. Develop common language to describe the key features	X	X				
	4. Maintain the cognitive demand	X	X			X	
Implementing a task	1. Individual work			X	X	X	X
	2. Group discussion				X	X	X
	3. Preparation for sharing group work			X	X	X	X
Orchestrating student work	1. Anticipating	X					
	2. Monitoring		X	X	X		X
	3. Selecting	X	X	X	X	X	X
	4. Sequencing	X	X	X	X	X	X
	5. Connecting	X	X	X	X	X	X

Note: X- stands for occurrence of an event in relevant sessions

Table III. Major themes from debriefings and second teachings

Group	Core instructional activities	Component	Lesson change
A	Launching a task	3. Develop common language to describe the key features	The instructor identified explicit terms unique to the task, recorded these on the board, and referred to them when discussing relevant mathematical concepts
	Orchestrating students' solutions	3. Selecting	Rather than have each group presenting their work to each problem, the instructor drew students' attention to the difference among different solutions across different groups
B	Implementing a task	2. Group discussion	Following independent think time, the students were directed to discuss their solutions prior to generating a poster rather than each group member being assigned a question to record on the poster
	Orchestrating students' solutions	3. Selecting	Rather than each group presenting their work to each problem, the posters were taped in the front of the classroom and the instructor directed students to compare/contrasts the answers to the first question, then the second question, etc
C	Implementing a task	2. Group discussion	In the second teaching, the students collaboratively developed solutions for their poster and the instructor was less leading in her interactions with groups
	Orchestrating students' solutions	3. Selecting	In the second teaching, the instructor called on groups that had different solutions (correct and incorrect) to explain their processes

Table IV.
Salient lesson changes

lessons were improved in implementing the tasks (individual work, sharing solutions before preparing posters, facilitating strategies for group activity). The majority of the suggestions from experts were implemented strategically in the second teaching.

Participants' perceptions of learning

Overall perceptions. All participants in the project ($n = 15$), including those groups excluded from case study analyses, completed the survey by selecting choices in terms of the extent to which the they agreed or disagreed with each of the given statements (SA = strongly agree (5 points), A = agree (4 points), UN = uncertain (3 points), D = disagree (2 points), and SD = strongly disagree (1 point)). With the exception of two instances in which participants marked uncertain, all responses (see Table V) were marked either SA or A. Table V also displays the average scores for each statement.

Perceived learning. The open-ended survey solicited participants' perceived benefits from LS participation. We compared responses to questions and classified them into five themes (column 1) and 15 categories (column 2) in Table VI.

From Table VI, two key ideas were mentioned by a majority of participants. First, participants mentioned the influence of LS on their professional growth, with attention to a willingness to adopt new instructional strategies. Second, participants described focusing on learning goals when making instructional decisions. Also important to note, participants indicated that they valued both the feedback from experts and the opportunity to collaborate with their peers.

Discussion and conclusion

Summary

Results revealed that all research lessons were improved toward emphasizing student-active learning through self-exploration, collaborative negotiation, and the development of

Item	SA	A	Ave.
Collaborative lesson planning			
1. Collaborative lesson planning helps us set clear learning goals	9	6	4.60
2. Collaborative lesson planning helps us anticipate students' solutions and students' learning difficulties	7	8	4.47
3. Collaborative lesson planning helps us develop various teaching strategies for dealing with students' learning differences	12	3	4.80
Teaching and re-teaching			
4. Seeing how the first lesson went well or got off track helps us understand how important it is to consider students' learning when drafting a lesson plan	10	5	4.67
5. To see how the second lesson is a significant improvement over the first lesson helps us understand how to improve teaching by adopting appropriate suggestions	11	4	4.73
6. To see how new problems occur in the second lesson although those problems occurred in the first lesson are resolved provides us with valuable opportunities to learn how to address unexpected problems or issues	9	5	4.53
7. Comparing the two research lessons helps us to see how we can improve teaching with the support of colleagues and outside experts	12	3	4.80
Debriefings			
8. The reflections on research lesson 1 and 2 help us understand the strengths and weaknesses of the research lessons	11	4	4.73
9. The comments and suggestions provided during debriefings help us to sharpen learning goals, find ways to overcome weakness, and improve teaching by focusing on student learning	11	4	4.73
10. The comments from outside experts provide different perspectives and alternative ways of looking at teaching, which are really helpful	11	4	4.73
The entire process of lesson study			
11. The entire process of lesson study (i.e. lesson planning, teaching, debriefing and re-teaching and re-debriefing) helps us deepen understanding of learning goals and student learning and improve teaching	11	4	4.73
12. The entire process of lesson study helps us develop capacity to reflect on our own teaching practice	10	5	4.67
13. The lesson study provides insights into the ways of improving our Professional Learning Community (PLC)	11	3	4.67

Table V. Participants' perceived benefits from participating in the lesson study

Theme	Code	*n*
Understanding student learning	Productive struggling	6
	Learning through mistakes	7
Improving teaching	Be a reflective teacher	5
	Strategies (questioning; organizing group activity; student-centered teaching)	8
	Setting and focusing on clear learning goals	9
Learning from experts	Focusing on learning goals when planning and teaching	4
	Importance of productive struggle	5
	Effectively orchestrating student work	4
Learning from enactment and reflection	Developing a better lesson and becoming a better teacher	5
	Learning about student thinking	2
	Learning and improving teaching	3
	Learning from others and realizing small change results in significant outcome	3
Long-term impact on participant's professional development	Implementation of effective mathematics teaching practices by adopting various strategies	10
	Collaboration with others	5
	Desire to try innovations and to be a better educator	4

Table VI. Participants' perceived learning mathematical connections through comparing/contrasting solutions. Participants improved their strategies for developing core instructional practices of TfPS, which included launching tasks, implementing tasks, and orchestrating students' solutions.

Considering the dynamic between enactment and reflection, the study detailed the nuances of how the ideas that emerged during reflection meetings guided participants to improve classroom instruction. Specifically, in the debriefings participants identified issues within the research lesson to which experts provided suggested strategies. Therefore, the participants were able to see how a small change in the lesson made a huge difference in learning outcomes. They not only saw the improvement, but also learned how to make it – how to reflect on the lesson and make a better lesson.

Beyond the learning of the specific strategies of TfPS, the participants also changed their views about learning and teaching and valued the collaboration with others.

Discussion

These results align with previous research in which LS has demonstrated its roles in improving teaching and promoting teacher learning (e.g. Huang and Shimizu, 2016; Lewis *et al.*, 2009). Yet, few studies have focused on LS as a mechanism for change and theoretical interpretation of why these changes could be made (Huang and Han, 2015; Lewis *et al.*, 2009). Since the Chinese LS includes a goal-oriented design and repeated enactment of a lesson with immediate feedback from knowledgeable others, this process is clearly a type of deliberate practice, which can improve teachers' performance (Ericsson *et al.*, 1993). With this in mind, we offer two implications that add to the literature.

First, this study enriches our understanding of how a Chinese LS can improve the specific instructional practice of TfPS. Results demonstrated the significant role of the experts in the LS process. By observing the lessons in person, experts provided immediate insights into the lesson revisions, allowing for participants to adopt and enact these revisions and witness the results. In this way, the feedback from experts, which was closely related to the occurrences in the classroom, provided a connection between research-based ideas and classroom practice and, thus, served as the key means for supporting participants' professional growth. Thus, the practical implication of these results highlights the importance of the expert participating in the LS process, as this person serves as the facilitator for change in participants' instructional practices.

Second, this study articulates how the interactions between enactment and reflection, within the context of LS and with immediate feedback from experts, can promote teachers' professional growth by the reinforcement of seeing salient outcomes (e.g. students' productive struggle and sharing of their work). Although the theory of deliberate practice includes enactment, reflection, and expert feedback, the theory does not account for the need of the individual to observe positive outcomes that are external to the individual, as is the case in the classroom where a teacher's motivation to continue practicing an instructional strategy is contingent upon student-related outcomes. As previously stated, it was important for the participants in this study to see the benefits of their changes on student learning. Therefore, the theoretical implication of this study points toward the need to consider the influence of student-related outcomes when framing deliberate practice within the classroom context.

Conclusion

This study makes significant contributions to literature and practice. Theoretically, it highlights the importance and necessity of the dynamics between enactment and reflection within the LS context. Facilitation by the knowledgeable other who has both theoretical and practical knowledge and is involved in the LS process in person is crucial. Although the dynamic among enactment, reflection, and experts' immediate feedback are featured in deliberate practice, this study enriches the theory by recognizing the additional component of student outcomes within the LS context. Practically, this study reveals the feasibility of adapting Chinese LS in the US setting and shows a pathway of implementing it on a larger scale so as to improve teachers' capacity for TfPS.

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Appendix. Open-ended participants' survey

Directions: please provide thorough responses to the following questions:

(1) How has your participation in Project IEMT impacted your understanding of students' learning of mathematics in classroom?

(2) How has your participation in Project IEMT impacted your teaching practices (such as teaching strategies and reflection on your own teaching and implementation of Common Core practice)?

(3) What are major things that you have learned from external experts during the school-based Lesson study if any?
(4) What are major benefits that you have obtained from observing, teaching, re-teaching, and debriefings? What are the unique benefits gained from the second teaching and re-debriefing in particular?
(5) What are the most important benefits from your participation in Project IEMT that you believe having long-term impact on your professional development?

Note: IEMT is the acronym of implementation of effective mathematics teaching for all students.

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