Exploring teacher learning through a hybrid cross-cultural lesson study in China and the United States

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Abstract

Purpose – This study aimed to explore teachers' learning processes through a hybrid cross-cultural lesson study (LS) because little is known about the learning process through this novel and promising LS approach.

Design/methodology/approach – This cross-cultural LS lasted over six months focusing on developing a research lesson (RL) related to linear functions/equations by addressing a commonly concerned student learning difficulty. The data collected were lesson plans, videos of RLs, cross-culture sharing meetings and post-lesson study teacher interviews. A cultural-history activity theory (CHAT) perspective (Engeström, 2001) was used as a theoretical and analytical framework, and contradictions were viewed as driving forces of teachers' learning. The data were analyzed to identify contradictions and consequent teachers' learning by resolving these contradictions.

Findings – The results revealed four contradictions occurring during the hybrid cross-cultural LS that are related to the preferred teaching approach, culturally relevant tasks, making sense of the specific topic and enactment of the RL. By addressing these contradictions, the participating teachers perceived their learning in cultural beliefs, pedagogical practice and organization of the lesson.

Research limitations/implications – This study details teachers' collaborative learning processes through hybrid cross-cultural LS and provides implications for effectively conducting cross-cultural LS. However, how the potential learning opportunity revealed from this case could be actualized at a larger scale in different

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cultures and the actual impact on local practices by adapting effective practices from another culture are important questions to be investigated further.
Originality/value – This study expands teacher learning through cross-cultural LS by focusing on contradictions cross-culturally as driving forces.

Keywords Lesson study, Hybrid cross-cultural lesson study, Cultural-history-activity theory (CHAT), Teacher collaboration, Teacher professional learning

Paper type Research paper

Introduction

Educators recognize cross-cultural studies offer insights into effective practices, and by adapting these approaches to their local sites, education can be more dynamic and adaptable (Clarke, 2006; Leung, 2001). Specifically, researchers have explored how teachers extend their learning through cross-cultural lesson study (LS) (Huang *et al.*, 2021; Isoda *et al.*, 2021; Sarkar Arani, 2015), yet teachers' learning processes and outcomes through LS across different cultural contexts are largely unclear (Huang *et al.*, 2021, 2023; Isoda *et al.*, 2021). This study aims to fill the gap by examining teacher learning from a hybrid cross-cultural LS in China and the US from a perspective of cultural-history activity theory (CHAT) (Engeström, 2001).

Review of literature

Lesson study is a teacher-centered and student-focused collaborative professional learning approach (Huang *et al.*, 2019; Lewis, 2016). The LS process includes four steps: study, plan, teach and reflect (Lewis, 2016). Recently, with the advancement of digital technologies, various online and hybrid LS models have emerged, expanding beyond traditional face-to-face implementation (Huang *et al.*, 2023). Although extensive research has documented the positive effects of face-to-face LS on teachers' professional learning, professional learning communities and students' learning outcomes (Cheung and Wong, 2014; Huang and Shimizu, 2016; Lewis and Perry, 2017; Willems and Bossche, 2019), researchers have called for more studies on the effectiveness and mechanism of virtual and hybrid LS (Huang *et al.*, 2023).

Cross-cultural lesson study and teacher learning

Implicit assumptions about teaching and learning can be explicitly made when comparing instructional practices across cultures which further facilitates appropriate adaptations based on local cultural values and traditions (Clarke, 2006; Leung, 2001; Mellone *et al.*, 2021; Weaver *et al.*, 2023). Stigler and Hiebert (1999) argued that teaching is a cultural activity that is determined by the cultural script of teaching. Moreover, within the LS context, Sarkar Arani (2015, 2016) developed a perspective for raising the quality of teaching through cross-cultural lesson analysis which could help explicate the locally hidden cultural script of teaching and seek alternative effective practices from another culture. A few researchers explored how cross-cultural online LS could promote participating teachers' development of knowledge and digital literacy (Huang *et al.*, 2021; Isoda *et al.*, 2021), but learning processes and outcomes of online cross-culture LS are lacking rigorous and systematic investigation.

Mathematics teaching and learning in China and the US

Cultural differences in mathematics teaching and learning between China and the US are well-documented (An *et al.*, 2004; Cai and Wang, 2010). Research revealed distinct features in Chinese mathematics instruction, such as developing mathematical reasoning and conceptual understanding through variation problem-solving (Ding *et al.*, 2022; Huang *et al.*, 2016). US mathematics instruction exhibited alternative approaches that typically emphasized procedural and low complexity problems while focusing on student understanding with concrete examples (Jacobs *et al.*, 2006; Cai and Wang, 2010). In addition, Chinese teachers emphasized abstract reasoning after utilizing concrete examples, while the US teachers emphasized finding multiple solutions using concrete examples, and highlighted classroom facilitation and students' engagement by considering individual students' learning styles (An *et al.*, 2004; Ding *et al.*, 2022). Specifically, research found that the US teachers preferred to use concrete presentations to solve problems, while Chinese teachers preferred to identify the structure of quantitative relationships and set equations to solve problems (Ding *et al.*, 2022; Huang *et al.*, 2016).

In addition, there have been fundamental curriculum reforms by incorporating research-based, innovative ideas in both countries in the last decade (NCTM, 2014; MOE, 2011). For example, in Chinese curriculum standards (MOE, 2011), it is recommended that teaching is a process teachers and students actively engage in, interact and co-develop math based on examining contextual situations. In the US, NCTM (2014) recommended eight research-based mathematical teaching practices, emphasizing problem-solving, facilitating meaningful mathematical discourse and students as active participants. These research findings and curriculum reform initiatives help understand the cultural scripts of teaching in the US and China that impact teachers' lesson planning and teaching during the LS process (Stigler and Hiebert, 1999).

Theoretical framework

Not only is teacher learning influenced by culture (Opfer and Pedder, 2011; Stigler and Hiebert, 1999), but also leading researchers employ culturally based frameworks such as communities of practice (CoP) (Wenger, 1998), interconnected model of teacher growth (Clarke and Hollingsworth, 2002) and CHAT (Engeström, 1987) to investigate teacher learning (Lee and Tan, 2020; Robutti *et al.*, 2016; Widjaja *et al.*, 2017; Wake *et al.*, 2016). Each has a different focus for framing learning such as participation and identity (Wenger, 1998), knowledge and practice (Clarke and Hollingsworth, 2002) and goal-oriented activity (Engeström, 1987). This study uses CHAT as the theoretical lens described in the following.

CHAT depicts an activity system consisting of three key components: subject (i.e. people involved), instruments (e.g. skills, knowledge and language) and object (e.g. lesson). It has evolved into a second-generation activity system that includes the community, where individuals collectively pursue a goal following certain rules and division of labor (Engeström, 1987; Leont'ev, 1981; Vygotsky, 1978).

Engeström (2001) further developed a third generation of CHAT that considers multiple interconnected activity systems and focuses on understanding learning that takes place when different activity systems collaborate on a shared problem (Engeström, 2001). The shared problem becomes the object of the interacting complex systems. From the perspective of CHAT, the LS process represents a typical activity system. Teachers and researchers (subject) collaborate as a community with assigned roles, such as enacting teachers and facilitators (division of labor). They collectively study a topic, plan a research lesson (RL) and then teach, observe and debrief the lesson following specific protocols and norms (rules).

Based on the study of instructional materials and use of technological tools (instruments), the LS research team collaboratively developed the RL (object) to achieve their LS goals (outcome). In this study, we adopted the third generation of CHAT, involving two interacting activity systems: Chinese LS and the US LS teams (see Figure 1). When the two activity systems interacted, the initial object, RLs based on local practices, transformed into a new object, lessons inspired by cross-cultural exchanges. Thus, the RL served as a boundary object (Akkerman and Bakker, 2011) jointly constructed through the interaction of the two systems, facilitating learning through boundary crossing (Engeström, 2001; Engeström and Sannino, 2010).

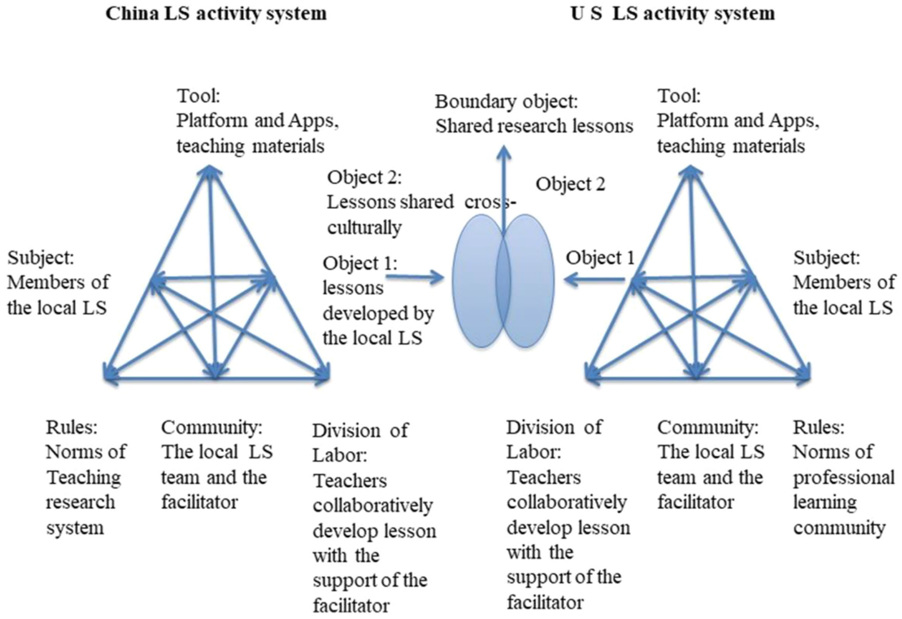


Figure 1.
Hybrid cross-cultural LS activity systems

Source(s): Authors' own creation

CHAT emphasizes contradictions as driving forces of promoting expansive learning within and between activity systems (Engeström, 2001, 2016). Contradictions, which are accumulating structural tensions, have the capacity to address problems and foster innovation (Engeström, 2016). Expansive learning refers to "learning in which the learners are involved in constructing and implementing a radically new, wider and more complex object and concept for their activity" (Engeström and Sannino, 2010, p. 2). Engeström (2016) classified four types of contradictions: (1) Primary contradiction arising from constituent components of the central activity (e.g. subject, object, community and tool), (2) secondary contradiction from the interplay between components (e.g. how to use "tool" to transform "object"), (3) tertiary contradiction from differences in goals/motives (e.g. differences between the traditional goals and reform-oriented goals within a system) and (4) quaternary contradiction from differences between the central activity and neighboring activities in a complex system (e.g. different objects/goals between two systems).

These contradictions not only generate disturbances and conflicts, but also prompt attempts to change the activity. CHAT views contradictions leading to the emergence of new objects, concepts and motives during navigation of the contradictions (Engeström and Sannino, 2010). Previous research has explored teacher learning in LS from a CHAT perspective (Huang *et al.*, 2021; Wake *et al.*, 2016), while this study extends by establishing a hybrid LS partnership between teachers from China and the US. Research questions follow.

RQ1. What were the major contradictions related to the transformation of boundary objects during the hybrid cross-cultural LS?

RQ2. How did the participating teachers perceive their learning through navigating the contradictions during the hybrid cross-cultural LS process?

Methods

The setting, goal and cross-cultural LS process helped shape this study and allowed for the data collection and analysis.

The LS team and the goal of the cross-cultural LS

Guided by three researchers, teams from China and the US joined the LS to collaboratively develop best practices to teach an agreed-upon topic addressing a student learning difficulty. Specifically, research indicates that developing algebraic thinking is crucial and challenging in the middle grades around the world, and linear functions and equations are core content for developing algebraic thinking (Stephens *et al.*, 2017). The LS process encouraged mutual learning as both teams exchanged insights and reflected on their experiences.

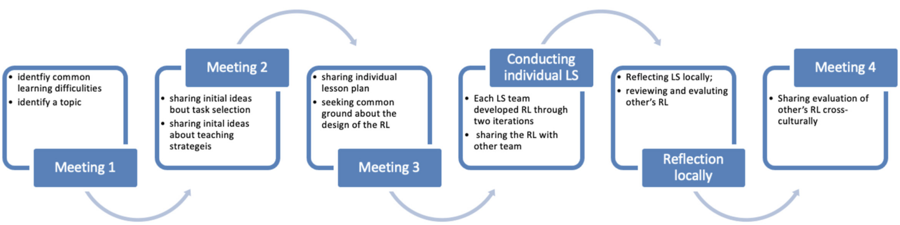
The Chinese LS team included six mathematics teachers from a Shanghai middle school, and the US team consisted of five interdisciplinary teachers from Ohio. Two taught mathematics, two taught language arts and one taught social studies. All had bachelor's degrees and over five years of teaching experience. Two university researchers facilitated the teams, while a third, with cross-cultural expertise, facilitated coordination and translation for cultural exchange.

In the Shanghai mathematics curriculum, equations and functions are two relatively independent parts. Linear equations (systems) are taught in grade 6, and linear functions in grade 8. In the Ohio curriculum at this LS school, linear equations and functions are covered in grades 6 and 7, while the concept of linear functions is introduced in grade 8.

Process of the hybrid cross-cultural LS

The three researchers met with the two LS teams to set the goal of developing a best practice of teaching a topic related to equations or functions addressing a common student learning difficulty. Initially, the cross-cultural LS teams decided to conduct the LS in a hybrid form, having both online (synchronous and asynchronous) and onsite activities (see Figure 2) due to the 12-h time difference between the two countries. Both LS teams had been previously involved in the LS process and agreed to use OneDrive to share relevant materials. The goal was that the US and China teachers would integrate each other's ideas to collaboratively create the RL and enact it following the LS process. Then they would reflect on the RL together and learn from one another. Zoom was used to conduct the online cross-cultural LS conversations that included two major components: cross-cultural exchanges and local LS implementation.

The cross-cultural exchange activities included four online meetings. Two meetings identified learning goals and examined content commonly taught across cultures. Another meeting involved the sharing of ideas for planning and further developing the RL. The final meeting was for debriefing and reflecting on the enacted RL. Based on the study of local instructional materials, each LS team generated initial ideas about their students' learning



Source(s): Authors' own creation

Figure 2.
Hybrid cross-cultural LS process

difficulties in relevant topics, created their initial lesson plan for sharing in meetings 1–3 and then revised lesson plans based on sharing ideas from meeting three.

Two iterations were included in the local LS that consisted of face-to-face RLs and debriefings on Zoom. Each LS team conducted and debriefed its own RL and observed the other's recorded RL through OneDrive before the final cross-cultural meeting four. The entire process is shown in Figure 2.

Data collection and analysis

Textual data were collected from each phase of the hybrid cross-cultural LS process, and meeting notes were shared via OneDrive. Both teams uploaded translated materials such as lesson plans and research to the folder before each scheduled meeting. The final exchange meeting was recorded and transcribed. To understand the participants' learning experience, a post-LS interview was conducted online and transcribed with three US teachers and four Chinese teachers on a voluntary basis. Data included meeting notes (N1-4), two RL transcripts (Chinese RL and the US RL), final exchange meeting transcript (EX) and interviews (CH I1-4 and the US I1-3).

To address the research questions, data analysis focused on identifying contradictions during the online meeting (e.g. quaternary contradiction) and ways of resolving the contradictions (during online meetings and activities within individual LS teams). An inductive and deductive coding approach was adopted (Corbin and Strauss, 2008) through three phases. The first author and a research assistant read all notes and transcripts, took memos about possible essential contradictions during each phase of the LS and how the identified contradictions were resolved contributing to the transformation of the "boundary objects," expanding teacher learning.

The research assistant created the initial coding table that included contradictions, possible resolutions and supporting data. Then, the first author and research assistant verified the contradictions and finalized the table, including four contradictions in alignment with the four online meetings. Moreover, three sub-categories were generated inductively within the last contradiction. Second, through multiple rounds of discussion, the first author and the research assistant developed a description of each contradiction, possible solutions and corresponding learning using evidence from the multiple data sets. Third, relevant data and descriptions were read by the US and Chinese LS team leaders who provided feedback on the descriptions. Based on the comments, the coding table was refined and finalized. Finally, the contradictions, their resolutions and corresponding learning were corroborated by the other researchers on the project.

Findings

Based on the data, the findings are presented in relation to the generation and navigation of four quaternary contradictions (Cs): (a) preferred teaching approaches, (b) culturally relevant contextual scenarios, (c) approaches to making sense of the same concept and (d) enactment of the RL.

Preferred teaching approaches

The first contradiction is the method of teaching linear equations involving fractions that was identified as a common struggle in the first meeting. The US teachers proposed an action-based, student-centered approach. The Chinese teachers suggested a more abstract mathematical concept-based and procedure-oriented approach. According to the data analyzed from the first meeting transcriptions, this contradiction emerged when the teachers were discussing what caused their students to lack mathematical understanding regarding linear equations.

The US teachers indicated students' difficulty in fraction operations as stated, "students are always struggling with fraction operations in general, it is even worse when solving an equation with fractions" (N1). According to the Chinese teachers, students "struggle with the distributive property and recalling negative integer rules, as well as fractions within equations" (N1). Regarding the commonly concerned student learning difficulty (solving equations with fractions), both the US and Chinese teachers investigated an innovative approach to better develop students' understanding of linear equations.

Based on the data from the initial meeting, the primary focus was teaching linear equations. The US teachers focused on hands-on learning to solve linear equations, suggesting writing linear equations on the floor for kinesthetic learning, fostering problem-solving skills. Furthermore, the US teachers believed that "creating lessons that immersed students into a real-life scenario while learning a mathematical concept at the same time" (N1) was the best approach.

However, the Chinese teachers believed that, while action-oriented methods benefit elementary students, middle grades should emphasize abstract thinking such as distributive property and operation rules. Thus, the Chinese teachers wanted to focus on procedural-oriented lessons, leading students to apply knowledge to real-life scenarios.

The difference in their favorite methods of teaching mathematics (abstract thinking vs concrete activity) is aligned with research findings (An *et al.*, 2004; Ding *et al.*, 2022). Therefore, teachers from both LS teams tried suggested feasible approaches to ease the tension such as a role-playing strategy, and the Chinese teachers were willing to explore the novel ideas. In addition, both Chinese and the US teachers agreed that word problems were difficult for their students, and that real-world application was important. Thus, the goal of each LS team was to create a lesson that included solving linear equations in contexts of role-playing to be discussed in the next meeting. The resolution of this contradiction may ignite the US teachers' thinking about the appropriateness of the action-oriented approach at various levels and opens a new window for the Chinese teachers to explore a novel approach. However, how to design daily problem scenarios for the RL resulted in a second contradiction.

Culturally relevant contextual scenarios

The second contradiction involved identifying a contextual task scenario for developing students' understanding of linear equations (concept and application). The US team suggested a role-playing scenario related to car selling or renting, while the Chinese team suggested a scenario related to online shopping with different discounts because of a Chinese festival that was quickly approaching.

While the consensus was to create a scenario for linear equations related to a real-life event by role-playing, there were still challenges. Chinese teachers were concerned that Chinese students might have difficulty understanding the car selling/renting problem scenario because they take public transportation without any experience in buying and renting cars. Another concern was the difficulty finding an appropriate situation that could be used for role-playing. The US teachers were concerned with the Chinese teachers' example of online shopping for festivals and how shopping works in a Chinese mall versus a US mall. For instance, the festival approaching in China was Double 11 on November 11 when various discount promotions occur to attract customers. The closest similarity to a US context was Black Friday, a consumer-focused discount day following the major US holiday known as Thanksgiving.

In the meeting, the US teachers also suggested membership programs to reach a consensus with the Chinese teachers. The US team suggested a sock of the month club to go along with the idea of a membership program, but one Chinese teacher mentioned, "Students in China need to be sure that they understand the idea of buying socks monthly. Belonging to a 'sock of the month' seems foreign to the Chinese" (N2). According to the Chinese teachers, membership programs are run by the same company in the mall, which is different from the malls in the US.

The data suggested differences in shopping experiences between the two cultures, but the teachers realized that online shopping was a more common scenario. Because the US and Chinese teachers believed that incorporating an online shopping scenario into their lesson would help students improve mathematical understanding of linear equations, they used the scenario for the RL. However, when designing the lesson using the commonly agreed scenario, a third contradiction occurred.

Approaches to making sense of the same concept

The third contradiction was in making sense of the concepts. The US teachers suggested exploring the concept of linear equations through real-life situations, while Chinese teachers' inclinations were to have students learn the content and apply the knowledge and skills to real-life situations.

During the third meeting, a US teacher stated, "With real-life examples, we can talk through and rationalize real-world situations." The US teachers mentioned that with this approach, students would be encouraged to uncover multiple solutions and be creative with their strategies to obtain the answers. The US teachers suggested a lesson example about a product titled Box of Socks and focused on finding the best deal in various membership programs, a concept well known by students in this US classroom. Students were to use linear equations to evaluate the best option.

The Chinese teachers had a different perspective, believing in "focusing on how to use [the] concept of linear functions and then apply [it] successfully in real-life scenarios" (N4) with greater emphasis on the abstract ideas behind what a function is. Chinese teachers suggested a lesson focused explicitly on how to develop the concept of linear functions and then had students apply what they learned into a real-life scenario. Chinese teachers expected their students to have the background knowledge required to apply it to festivals and other real-life events; therefore, abstract concepts would be directly taught in-depth with high rigor so that students could then apply them within various contexts. The Chinese approach presents a compromise between exam-oriented mastery teaching (Huang *et al.*, 2016) and reform-oriented teaching for problem-solving (MOE, 2011), while the US approach reflects reform-oriented teaching through contextually based real-world problems (NCTM, 2014).

Although differences existed, both teams agreed to develop an RL based on the shared ideas and their best practice. The resolution to the third contradiction was to demonstrate their own best practice of teaching a similar content while incorporating some shared ideas into RLs. However, the recorded and transcribed RLs revealed salient differences between the two RLs that formed the fourth contradiction.

Enactment of the research lesson

The fourth contradiction is related to the enacted RLs. Although Chinese and the US teachers had the same overarching goals of their lessons, a fundamental contradiction was identified. According to the data from the RL recording, the US approach fully engaged students in context, communication and sense-making about linear equations through the given scenario and allowed students to explore options to solve linear equations; whereas the Chinese RL offered rich opportunities for students to explore mathematics knowledge, skill application and problem-solving with limited student engagement. The fourth contradiction was described by teachers with three sub-themes: cultural beliefs concerning mathematics teaching and learning; pedagogical practice such as the pace of the lesson and teaching style; and class structure, including class size, lesson duration and the allowance of group work.

The teachers from both cultures tried to resolve these contradictions by seeking the improvement of their own practice through adapting effective practice from the other culture.

Cultural beliefs concerning mathematics teaching and learning. According to the data from the RLs, the Chinese lesson approached mathematics more abstractly so that students could apply the concepts to real-life scenarios. However, the US lesson focused on immersing students in a real-life task and learning mathematics through problem-solving. Teachers from both countries noticed this contradiction. One Chinese teacher stated, "I think their classroom is more focused on serving life. Our middle school math is more abstract" (CH I2). Another said, "We [Chinese teachers] tend to have students apply their knowledge to solve problems after having a solid foundation of knowledge" (CH I4).

Another Chinese teacher observed the US teachers teaching content as a cohesive body of knowledge within one class, providing an overview of concepts and their interrelation. In contrast, Chinese teachers divided content into smaller, rigorous sections to prepare students for direct knowledge application. A US teacher had similar remarks and deduced that this was because the "US lessons are more practical while Chinese lessons are more high technical mathematics rigor" (EX). A Chinese teacher explained that teaching highly technical mathematics rigorously allows "Chinese students to feel that math is abstract . . . the advantage of the Chinese approach is that students won't have a barrier to solve the linear equation after understanding the math. Students will be less likely to make mistakes because they have built a foundation before solving the problem" (CH I4). A couple of US teachers mentioned that the Chinese approach was "like running a business" (US I2, I3) – quick, efficient and with high expectations.

Data revealed that teachers from the US and China perceived the impact on their professional learning. One Chinese teacher stated, "I will add some content in certain lessons which are closely related to real life, such as word problems, the application of linear function, the application of quadratic function, etc., so that students can have more time and space to think and communicate" (CH I1). Echoing this quote, two other Chinese teachers felt that their perspective of teaching was impacted and desired to implement more real-life, problem solving, and group activities.

Two US teachers learned they should be more willing to create more in-depth mathematics problems allowing students to dive deeper into the abstract concepts at play during each lesson and felt they needed to trust that their students are capable of higher order mathematical thinking. For example, one US teacher said, "It [the Chinese RL] made me reflective about the abilities of students around the world, and how they just respond to the expectations of teacher and how I could change things for the better . . . I can challenge my students more and they can rise to meet these expectations" (US I1).

Pedagogical practice. A couple of the Chinese teachers noticed that "the China lessons included fast [paced], formal activities that gave more mathematics to students . . . the US lessons included slow [paced], informal activities and allowed students to explore and be engaged" (EX). Another Chinese teacher stated, "I think the advantage of the American approach is that it is very close to real life. At the beginning of the introduction, the instructor talks about their subscription service, students are also very familiar with, immediately attracted the attention of students to the lesson" (CH I3). Another Chinese teacher noted,

> The US teachers allow students to actively engage in mathematical activities, communicating and solving problems for a very long time. Whereas we favour a process where the teacher imparts knowledge and then the students solve a particular type of problem in a shorter time and then students practice it over and over again . . . I feel that the lessons in China are more rigid and the lessons in US are more flexible (CH I4).

One US teacher stated, "the China teacher started with easy problems and then they progressed to making them more challenging and making the students really work through the story problem and think about processes in different ways" (US I3).

The salient difference in the pedagogical approaches between the two RLs prompted teachers from both countries to rethink their own practice and seek alternative approaches by adapting effective practices from the other culture. For example, the US teachers noted that they should trust their students' abilities and ask more in-depth questions; one US teacher stated, "Maybe I should come up with a few tasks that ask them to approach those from different perspectives; ask them to work backwards instead of just making it all the same fairly simple process; push them to do something a little bit harder" (US I3). Correspondingly, one Chinese teacher mentioned,

> The US teacher did a great job engaging the student and catering to them, thus [it] has inspired me to allow students more time to think and discuss in class, and to decrease the number of problems and focus on a few important problems that can allow the students to learn deeper mathematics from them. (CH I1)

Another Chinese teacher mentioned, "she would like to continue to utilize real-world problems to help student learning in the future" (CH I2) and detailed how she would like to spend more time focusing on student understanding of meanings of parameters of k (slope) and b (intercept) within a linear function as the US teacher did.

Class structure. According to the demographic data, not only was the US classroom a significantly smaller in size (20 students) than the Chinese classroom (45 students), but also the US class had 40-min classes versus 25 min for a typical Chinese lesson. The time constraints forced the Chinese teachers to teach at a rapid pace. All US teachers recognized that the math class in Shanghai moved through the content at a much quicker pace. A Chinese teacher mentioned that this [fast pace] was due to syllabus constraints as well as the looming pressures of examinations in China, and further pointed out, "They (US RL) are more about taking care of all the students, so the teacher talked about a relatively basic problem that everyone was able to solve" (CH I1). Chinese teachers also noticed that US teachers had their students sitting in groups; the teacher talked to each individual student when circulating in the class, and each student was able to explain their thoughts on the problems. The US teachers noticed that the Chinese teachers had students sitting in groups of boys and girls separately, and the teacher talked in public to all students, with students answering on behalf of the group when called upon.

According to interview transcripts, the US teachers were impressed with the amount of control Chinese teachers had in the classroom, the high expectations and the ability to fit all the content in such a small window. One US teacher stated that this study taught them that "we need to be expecting some more from our students, we need to be pushing them more when it comes to how much math they can do. Over time, it would definitely encourage our students to understand math at a deeper level" (US I3). The Chinese teachers learned that it would be beneficial to have students sitting in groups to be able to conduct more discussions and reflections over the content, where students can feel that "math exists in your [their] lives" (CH I4). Another Chinese teacher's takeaway was to create an environment where "student interaction and participation are included into the teaching design" (CH I3).

Although all teachers showed willingness to adapt some effective practices from the other side, they realized that a simple copy would not work. A few of the Chinese teachers appreciated the benefits of the US approach but realized that implementation cannot be done in the same way and all at once. For example, one Chinese teacher explained how to learn from the US side while retaining her own strengths:

> I think our side of math develops abstract thinking, which is our strength. But for students with poor grades, they can't think abstractly at all, so this time they need some help, for example, some concrete examples in the American side of the class, . . .it is also to let students know more about the relationship between mathematics and our real life. [CH I3]

Similarly, the US teachers noticed their students could have more rigor as Chinese teachers promoted and suggested an approach to balancing imparting of knowledge and application of knowledge. For example, one US teacher stated:

> It (the Chinese approach) seems like a very efficient way to impart knowledge. With the American one, I was wondering how many of the kids really understood mathematics . . . we're kind of thinking of it as the situation, not as a mathematics exercise . . . We need both ends not one or the other. Students need to learn the rules and how to function them, but also be able to get results you want in a hands-on situation. [US I3]

Teachers from both countries mentioned that finding a balance between the mathematics concepts and student engagement is important for future lesson planning.

Summary

Throughout the cross-cultural LS, when interacting with unfamiliar ideas and practices, teachers from both LS teams faced many conflicts as featured by the four contradictions. They collaboratively explored the resolutions to the contradictions. The boundary object (shared RLs) transformed from *abstract object*: ideas about teaching a similar topic addressing commonly concerned difficulty (C1), to *transitional object*: selecting culturally relevant teaching scenarios (C2) and making sense of a similar content (C3), and finally to *concrete object*: different enacted RLs with the same goals (C4), consequently driving expansive learning.

By resolving C1, the US teachers developed a wider concept of an action-oriented approach that student grade level and learning style should be considered, while Chinese teachers extended their teaching strategies including role-play. Through resolving C2, teachers developed their concept of realistic scenarios: the authenticity and appropriateness of contextual scenarios are culturally relevant. By resolving C3, teachers had opportunity to rethink their preferred teaching approaches: teaching through problem-solving versus teaching for problem-solving. By navigating on C4, salient differences between the two RLs encouraged teachers to reflect upon strengths and weakness of their own cultural script of teaching and seek alternative ways of raising the quality of teaching by adapting effective practice from the other culture (Clarke, 2006; Leung, 2001; Sarkar Arani, 2015). For instance, the US teachers realized they could raise their expectation of students, and Chinese teachers believed they should make mathematics better connected to students' daily life.

Discussion and conclusion

The results provide valuable insights into teachers' learning through hybrid cross-cultural LS. Henceforth, the contributions and implications to research are discussed in the following section.

Expanding teachers' learning in a hybrid cross-cultural LS context

Research has shown that analyzing RLs from cross-cultural LS can help researchers identify the cultural script of teaching and seek alternative ways of raising quality of teaching (Sarkar Arani, 2015, 2016), but what *participating* teachers learned from cross-cultural LS has been missing. Some cross-cultural LS research evidenced changes in participants' knowledge, but the learning mechanism has been largely unclear (Huang *et al.*, 2021; Isoda *et al.*, 2021).

Although Huang *et al.* (2021) examined the teacher learning process within one of the two cross-cultural LS team from the CHAT perspective, it is not clear how the cross-cultural interactions contribute to each LS team's learning. Therefore, this study analyzed teachers' learning processes through cross-cultural LS by focusing on the interactions between two LS activity systems. Furthermore, this study explored participating teachers' learning through the entire process of hybrid, cross-cultural LS: study, planning, enacting and evaluating RLs. Results revealed that teachers expanded their learning by resolving and/or navigating contradictions caused by cultural differences.

The effect of this cross-cultural LS is significant because the US RL demonstrated several effective teaching practices as NCTM (2014) recommended, such as the use of mathematics tasks that promote problem-solving, sense-making and productive discourse. Students' engagement and extensive communication in mathematics classrooms is eye-opening to Chinese teachers. On the other hand, the Chinese RL revealed many features connecting mathematics concepts, mathematics reasoning and explanation as described in literature (Ding *et al.*, 2022; Huang *et al.*, 2016), providing fresh ideas for US teachers.

Using hybrid cross-cultural LS, a transformative zone between teachers' current and possible practice was actualized toward improving instruction (Yuan and Matney, 2018). Furthermore, cross-cultural LS encouraged teachers to deconstruct their own pedagogical practice and seek a new instructional method, promoting student learning and altering teacher beliefs. Therefore, this study demonstrates how the contradictions between two activity systems could be the driving force for promoting teacher learning, and the detailed process and profound reflection deepened an understanding through hybrid cross-cultural LS.

Implications, limitations and future research

This study has several implications. Theoretically, CHAT is a useful framework for investigating teacher learning (process and product) through hybrid cross-cultural LS. Practically, with the advancement of digital technology and Internet, hybrid cross-cultural LS could be a feasible and powerful extension of traditional LS by eliminating geographical distance and expanding learning through exploring alien innovative ideas.

There are limitations of this study. First, teachers' learning through cross-cultural LS is impacted by both cross-cultural exchanges and the local LS process. However, this study only focused on the contradictions and teacher learning of the cross-cultural component without examining the effect of local LS on teacher learning. Second, although teachers from both countries indicated their intention to adopt some ideas in their future practice, this study did not examine the follow-up lesson based on a revised lesson plan by adopting ideas from the final cross-cultural evaluating meeting. In further studies, both teacher learning from the local LS process and cross-cultural exchanges should be examined simultaneously. How adaption of ideas from other cultures into local practice impacts students' learning outcomes should be examined longitudinally. Although the contradictions and their resolutions found in this study should carefully be considered in the light of their unique contexts within these two countries, how the benefits of this small case study can be scaled up and sustained is a crucial and important question to be explored in the future.

Concluding remarks

This study clearly demonstrates how teachers expanded their learning by navigating various contradictions throughout the hybrid cross-cultural LS from the perspective of CHAT. When teachers explored pedagogical strategies suggested by another culture, they deconstructed their implicit assumptions about mathematics teaching and learning and sought alternative approaches to improve their practice (Clarke, 2006; Huang *et al.*, 2021; Isoda *et al.*, 2021; Leung, 2001).

Although there are some challenges in conducting cross-cultural LS (Weaver *et al.*, 2023), it is a rewarding to participants and strengthens instructional practice.

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