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ORIGINAL ARTICLE

Critical factors in the adaptation and implementation of Japanese Lesson Study in the Australian context

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Abstract Worldwide interest in Japanese Lesson Study as a vehicle to improve mathematics teaching practice through professional learning has left largely unanswered questions about the extent to which it can be replicated elsewhere. This paper reports on a small-scale research project, *Implementing structured problem-solving mathematics lessons through lesson study*, carried out in three Australian schools during 2012, and continued in a modified form during 2013 and 2014. Two major aims of the project were to investigate critical factors in the adaptation and effective implementation of (1) structured problem-solving mathematics lessons, and (2) Japanese Lesson Study as a model for teacher professional learning in the Australian context. This paper discusses the specific affordances that contributed to both the implementation of structured problem solving and to teachers' professional learning as a result of their participation in this project, as well as the constraints encountered, and the implications of these for the sustainability of lesson study in the Australian context. Critical factors identified by the teachers as contributing to the success of the project included the opportunities for in-depth lesson planning, the presence of large numbers of observers at the research lessons and the post-lesson discussions, and the insight provided by the "knowledgeable other". Major constraints included the difficulty in finding suitable problem solving tasks to match the Australian curriculum, and the teaching culture that emphasises small-group rather than whole-class teaching.

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1 Introduction

Lesson study first came to worldwide attention as a vehicle for professional learning through Yoshida's (1999) doctoral dissertation and Stigler and Hiebert's (1999) accounts of Japanese structured problem-solving lessons based on the *Third International Mathematics and Science Study* (TIMSS) video study. Since then, there has been phenomenal growth of lesson study as a vehicle for teacher professional learning. By 2004, adaptations of lesson study were taking place in over 335 schools across 32 states in USA (Lewis et al. 2006), with more recent large-scale adoption in the UK (e.g. Department for Children, Schools and Families 2008), the Netherlands (Kaskens and Goei 2016) and Ontario, Canada (e.g. Miller 2010), as well as implementation in South-East Asia (e.g. Indonesia, Malaysia), South America, many African countries (APEC-HRD Project, n.d.), and Australia (e.g. Hollingsworth and Oliver 2005; Pierce and Stacey 2009).

However, as Stigler and Hiebert (1999) point out, efforts at improving teaching often ignore the fact that teaching is a cultural activity, which implies gradual change and the need to take into account the cultural assumptions underpinning teaching and learning. Moreover, prior research suggests that teachers outside Japan often focus only on superficial aspects of lesson study (e.g. Robinson 2007; Perry and Lewis 2008; Inoue 2011). Thus questions about the extent to which lesson study can be replicated elsewhere remain (Perry and Lewis 2008; Lewis et al. 2009; Shimizu and Williams 2013), as do questions about the extent to which teachers can adopt structured problem-solving as the basis for research lessons.

Lewis et al. (2006) argue that there are three critical research needs if the full potential of lesson study is to be realised: (1) expansion of the descriptive knowledge base on lesson study, including knowledge of its possible adaptations to contexts outside of Japan; (2) explication of the mechanisms through which lesson study results in improvement in practice; and (3) design-based research cycles "that may produce 'usable, actionable, and adoptable' artifacts that 'leverage learning' in other sites" (p. 5).

This paper reports on a small-scale research project, *Implementing structured problem-solving mathematics lessons through lesson study,* carried out in three Australian elementary schools during 2012, and continued in a modified form in 2013 and 2014. Two major aims of the project were to investigate critical factors in the adaptation and effective implementation of (1) structured problem-solving mathematics lessons, and (2) Japanese Lesson Study as a model for teacher professional learning in the Australian context. A third aim was to investigate the effects of participation in a program of Japanese Lesson Study on teachers' pedagogical content knowledge in mathematics. This paper addresses the first two of these aims.

In earlier work, Groves and Doig (2010) discussed some of the cultural and systemic affordances and constraints in the adaptation and implementation of Japanese Lesson Study. In this paper we discuss the specific affordances that contributed to both the implementation of structured problem solving and to teachers' professional learning as a result of their participation in this project, as well as the constraints encountered, and the implications of these for the sustainability of lesson study in the Australian context.

2 Key features of Japanese Lesson Study

Japanese Lesson Study (JLS) is a professional learning activity whose origins can be traced back for over a century. Unlike many Western initiatives, lesson study in Japan is neither funded nor mandatory. The school-based version, which has attracted most attention outside Japan, is organized by teachers themselves and pervades elementary school education and, to a lesser extent, secondary school education, across the country, with teachers researching their own practice in school-based communities of inquiry. Lesson study also occurs at regional and national levels, where "open lessons" use a similar format for research lessons that explore new ideas about teaching and curriculum (Stigler and Hiebert 1999).

School-based Japanese Lesson Study has four components: (1) formulation of over-arching school goals related to students' learning and long-term development; (2) group planning of a *research lesson* addressing these goals; (3) one team member teaching the research lesson while the planning group, and others, observe in order to gather evidence of student learning; and (4) the post-lesson discussion where the planning group and other observers (usually including an "outside expert") discuss and reflect on the evidence gathered during the lesson, using it to improve the lesson, the unit, and instruction more generally (Perry and Lewis 2008, p. 366).

The impetus for the widespread interest in lesson study originated from the video and print descriptions of the "typical" Japanese Year 8 lessons captured as part of the TIMSS video study. These lessons followed a pattern, which Stigler and Hiebert (1999) referred to as "structured problem solving" (p. 27), a major instructional approach designed to create interest in mathematics and stimulate creative mathematical activity (Takahashi 2006). In Japan, almost every research lesson in mathematics is based on "structured problem solving" (Fujii 2013, p. 4). The structure of Japanese problem-solving mathematics lessons has evolved over four decades, originating from a desire to introduce open-ended problems in order not only to enhance students' higher-order thinking, but also to enable students to use their previous knowledge and skills to learn something new through the process of solving a problem (Becker et al. 1990; Takahashi 2006; Ueda et al. 2014).

Major characteristics of these problem-solving lessons include:

- the *hatsumon*—the single *thought-provoking question* or *problem* that students engage with, which is the key to students' mathematical development and mathematical connections;
- *kikan-shido*—the *purposeful scanning* that takes place while students are working individually or in groups, which allows teachers not only to monitor students' strategies but also to orchestrate their reports on their solutions in the *neriage* phase of the lesson;
- *neriage*—the *kneading* stage of a lesson that allows students to compare, polish and refine solutions through the teacher's orchestration and probing of student solutions;
- *matome*—the *summing up and careful review* of students' discussion in order to guide them to higher levels of mathematical sophistication (Shimizu 1999); and
- *bansho*—the *art of blackboard writing* that helps students visualize the flow of ideas from problem to solution to broader mathematical principles (Green 2014, pp. 12–13).

The *neriage* phase of a lesson—the "heart" of the lesson—begins after students struggle with the problem and come up with their own solutions. Through this process, "a teacher highlights important mathematical ideas and concepts for students to reach the goals of the lesson"

(Takahashi 2008, p. 5). Typically, this stage takes upwards of half the time of a lesson. Skillful blackboard writing, *bansho*, not only provides a visible record of the entire lesson that helps students remember, it is also an essential visual aid for students to help them participate in discussion while they compare, contrast, and clarify the ideas behind the different solution methods, thus assisting students to see the connections between and progression of different parts of the lesson (Takahashi 2006).

Critical in the process of planning a research lesson is the selection of the problem or task for the problem-solving activity through *kyozaikenkyu*—an intensive and complex investigation of a range of instructional materials, including textbooks, curriculum materials, lesson plans and reports from other lesson studies, coupled with a study of students' prior understandings (Watanabe et al. 2008). While teachers cannot engage every day in such deep *kyozaikenkyu,* conducting it for the purpose of research lessons leads to a deeper understanding of the curriculum and the mathematical content and goals underpinning it, as well as an appreciation of the importance of matching problems to both the mathematical goals of the lesson and students' prior knowledge (Doig et al. 2011).

In JLS, an extensive lesson plan—usually five to ten pages long—is developed by the planning team. Copies are given to all observers at the research lesson and up to a week in advance to the "outside expert". Lesson plans for school-based lesson study typically include the over-arching goals for the lesson study; goals for the unit of work in which the lesson is embedded; a description of the students' mathematical knowledge regarding the topic; an outline of the unit of work and its relationship to the topic in earlier and later years of school; the specific goals of the lesson; and a detailed plan for the lesson including the activities, key questions and comments the teacher plans to use, key points for the teacher to remember, and, most importantly, anticipated student responses that help guide the teacher in selecting students to share their solutions in the *neriage* stage of the lesson.

Public observation and debriefing of research lessons is a key feature of JLS. Typically a research lesson will be observed by all members of the lesson planning team, the school principal, the other teachers at the school (or the other teachers in the same subject area at secondary schools), and an "outside expert" who acts as the final commentator at the post-lesson discussion. Depending on the scale of the research lesson, there may be many additional outside observers—having 50–100 observers is not be unusual. Observers focus on student learning and are expected to base their comments in the post-lesson discussion on evidence they have collected during the lesson. The purpose is to promote thoughtful, data-focussed discussion of the lesson. The discussion, which is facilitated by a chair, begins with reflections from the teacher who taught the lesson. This is followed by reflections from other members of the planning team, comments and questions from observers, and finally by extensive comments from the outside expert.

In Japan, lesson study is widely viewed as a shared professional culture that provides a pathway for continuing improvement of teachers' pedagogical and content knowledge (Takahashi and Yoshida 2004; Murata 2011; Shimizu 2013). Teachers act as researchers in all phases of the JLS process: researching the curriculum, teaching resources, and known student misconceptions; and formulating their own research questions to be addressed through the research lesson and subsequent post-lesson discussion (Lewis and Tsuchida 1998; Takahashi and Yoshida 2004).

3 Methodology and design of the study

The *Implementing structured problem-solving mathematics lessons through lesson study* project adopted a Design-Based Research (DBR) approach, premised on a model of collaborative practitioner inquiry. DBR brings together a range of methodologies with the aim of bridging the divide between theoretical research and the complexities of educational practice in naturalistic settings (Design-Based Research Collective 2003; Dolk et al. 2010).

In DBR, the focus is on refining theoretical understandings through cycles of design, enactment in authentic settings, analysis, and re-design. Practitioners and researchers work closely together in DBR to implement innovative forms of learning and to study the means that are designed to support them in the contexts of practice. The iterative process of design, implementation, and retrospective analysis corresponds well with the JLS process of planning, observation, and reflection.

A key feature of DBR is the way in which practitioners (in our case teachers) work collaboratively with researchers to bring about changes in practice, thus helping researchers to distinguish between "a 'lethal mutation'… that no longer captures the pedagogical essence of the innovation… [and] a productive adaptation… that preserves this essence, but tailors the activity to the needs and characteristics of particular classrooms" (Design-Based Research Collective 2003, p. 6).

In many non-Japanese adaptations of JLS, decisions are made *a priori* to dispense with certain features of JLS—see, for example, Williams et al. (2013, p. 158), where it was decided that teachers would "develop a *variation* of the Japanese lesson study model" which resulted in "one teacher leading the session but hav[ing] the rest of the lesson study team actually working with a group of children rather than simply observing". By way of contrast, every attempt was made in our project to implement JLS as

"authentically" as possible—that is to incorporate the key features described earlier in this paper, including adopting the structured problem-solving pattern for the research lessons—in order to research the possibilities for a productive adaptation of JLS that preserves its essential features, rather than a "lethal mutation".

Lesson study engages teachers in the collection and interrogation of data on the effects of their lesson on their students' learning, through observers' detailed evidence obtained during the research lesson and shared in the post-lesson discussion, where many "fresh eyes" enable teachers to reflect on teaching and learning more broadly than is possible just through their own reflections. Evidence derived from such data can also form the basis for the researcher's inferences and lead to design principles for future implementation cycles (Lewis et al. 2006).

In keeping with the use of a DBR approach, the research team worked with a team of two Year 3 and 4 teachers from each of the three participating schools during 2012 to explore ways in which key elements of JLS could be embedded into Australian mathematics teaching and professional learning. All three schools belonged to the same network of 27 government schools located within a single school region. Teachers were supported not only by members of the research team but also by a key leading teacher at each school (e.g. a curriculum specialist or "numeracy coach"[1]) and the network numeracy coach, Paula.[2]

Participating teachers took part in an initial whole-day professional learning session on JLS in July, and participated in one lesson study cycle during each of Terms 3 and 4 of 2012. (The school year in Australia consists of four ten-week terms starting in late January.)

Each lesson study cycle involved two cross-school teams of three teachers and two coaches planning a research lesson, based on their adaptation of the same problem, during four two-hour planning sessions, with one member of each team teaching the lesson to their own class in front of observers. Despite the fact that school-based lesson study in single schools formed the basis for this project and that this is the most popular model in Japan, a cross-school model was chosen to enable a group of enthusiastic teachers, working at approximately the same year level, to begin to develop a culture of lesson study focussing on elementary school mathematics, in a similar vein to the beginnings of the Chicago Lesson Study Group (Takahashi, n.d.).

In addition to the project participants, key staff at each school and all interested teachers who could be released from their classes at the time of the research lessons were invited to observe the lessons and take part in the post-lesson discussions. The school and the research team also invited other professionals such as teachers and mathematics educators to observe the research lessons and take part in the post-lesson discussions, resulting in 20–30 observers for each research lesson. Given the importance of the role of the "outside expert" or "knowledgeable other" (Takahashi 2014), the knowledgeable other for the two Term 3 research lessons was Dr Max Stephens, an Australian expert on JLS, while for the Term 4 research lessons, our Japanese collaborator in this project, Professor Toshiakira Fujii, came to Australia to act as the knowledgeable other.

While the two lesson study cycles were similar in format, in the spirit of DBR modifications were made based on feedback, observational and other data, and the first-hand experiences of the four researchers, who acted as participant observers at all planning sessions (two per planning team), conducted the initial professional learning day, attended all four research lessons, and participated in and chaired the subsequent post-lesson discussions.

During the first half of 2013, the project continued in two of the original schools, together with another school where Megan, one of the 2012 numeracy coaches, had relocated. This part of the project was supported by the school network due to the perceived benefit of the 2012 project in supporting teacher professional learning. During 2013, the third 2012 school, while not continuing its participation in the project, conducted one lesson study cycle in mathematics, led by the 2012 numeracy coach George, as well as a lesson study cycle in English language, led by the school's literacy coach. During 2014, the project team continued working with another new school where three of the participants from the 2012 project had relocated. In this part of the project, lesson study was again extended to include one research lesson in English language.

All 2012 planning sessions, research lessons and subsequent post-lesson discussions were video recorded. Three audio-recorded, semi-structured interviews (INT1, INT2, INT3) were carried out with each of the nine participating classroom and leading teachers, and the network numeracy coach, who took part in all of the activities.

Similar data were collected during the two parallel research cycles in 2013, although in this case there was just one interview with participating teachers and coaches (INT4). No data was collected from the third school, although members of the research team attended the mathematics research lesson, with one of the authors acting as the knowledgeable other at the post-lesson discussion.

Due to the fact that the research team was not able to participate in the planning sessions for the two mathematics lesson study cycles in 2014 and other extraneous factors, the only data available from the 2014 mathematics lesson

[1] Numeracy coaches are experienced teachers who provide curriculum leadership in mathematics teaching by working with individual teachers and teams of teachers to improve teaching and student learning.

[2] All names of teachers, coaches, and schools are pseudonyms.

study cycles were video recordings of the first and third mathematics research lesson and the subsequent post-lesson discussions. Due to the changed nature of our engagement with the new school in 2014, this paper is based only on data collected during 2012 and 2013.

All interviews (INT) and video recordings from the 2012 and 2013 post-lesson discussions (PLD) were transcribed, together with video recordings from some planning meetings (PM). Additional data sources included: field notes of planning sessions (FN); lesson plans for the research lessons (LP); copies of all student work produced during the research lessons (SW); and a total of six different joint presentations by participating teachers and members of the research team at two State and two National mathematics education conferences during the period 2012–2014 (CP). Audio-recordings of teachers' and numeracy coaches' contributions to some of these presentations were also transcribed.

The transcribed data were subjected to an iterative, thematic content analysis in the sense of Keller (2013, p. 18). Data sources were consistently and constantly reviewed in order to extract information regarding critical factors relating to the adaptation and effective implementation of structured problem-solving mathematics lessons and JLS as a model for teacher professional learning in the Australian context.

4 Implementing structured problem solving

Stigler and Hiebert (1999) point out that teaching is a cultural activity governed by implicit "cultural scripts" based on ingrained beliefs and assumptions "about the nature of the subject, about how students learn, and about the role that a teacher should play in the classroom" (p. 87). In this section we discuss the effect of cultural scripts on the implementation of structured problem-solving lessons in our project.

4.1 The Japanese problem-solving lesson structure

Participating teachers saw some aspects of the Japanese problem-solving lesson structure and its focus on sharing student solutions as a natural extension of their previous professional learning relating to questioning techniques to develop students' higher order thinking. However, they were initially highly sceptical of using a single problem (*hatsumon*) for an entire lesson, and even more sceptical of spending up to half the lesson time on sharing solutions (*neriage*), and using this as the focus for achieving their mathematical goals (*matome*).

Teachers were particularly sceptical that their students could participate effectively in an extended discussion of solutions in the *neriage* phase of the lessons, as exemplified by the following exchange during the second planning meeting of the first lesson study cycle (PM2).

> Megan: Should we be following the lesson structure or should we …?
> Keith: The reflection, I don't know about your … but my [class] I don't know if they could sit for a reflection for, I think, 20 min. Might be pushing it for some.
> Henry: Yeah, definitely. (PM2)

Other teachers also found it challenging to engage the children in these extended discussions.

> Some of the students – you need to get the kids used to the idea of discussing. (Camilla INT3)Time can be a challenge and also just building up the capacity to be able to sit for that long and discuss and share strategies when they're not used to it. (Lynn INT3)

Not only did teachers have no prior experience of teaching in this way, their school region had recently mandated a lesson structure comprising: a 5-min warm-up; a 5- to 10-min introduction; students working on a task for 35 min; and 5- to 10-min of sharing and reflection.

> I was following the… [region's model where] you spend a few minutes introducing – you do a warm-up…. And then you spend all this time working on it. And then 10 or 15 min of "This is what we did." End. [It's] quite different. (Camilla INT3)

Several teachers identified abandoning the mandated lesson structure as one of the most difficult changes in their teaching practice.

> Some people find it difficult enough to change other things in their practice [but] to turn a lesson structure on its head – that might be quite extremely difficult…. The challenge is not retraining but getting the kids used to a different structure. (Keith INT3)We came from the lesson structure that… we'd spent three years working on, to then take a different approach and highlight an area… that perhaps isn't as highlighted in our own lesson structure. …was a bit of a struggle initially for us. So I think that was one of our big parts that we have now implemented into our classroom. (Megan, CP2)

"Learning intentions" were a major issue for some participants as teachers at some of the schools were required not only to follow the region's lesson structure but also to write the learning intentions for the lesson on the whiteboard as part of their introduction to the lesson. As Narah pointed out:

> There's… such an emphasis on learning intentions in schools these days, teachers think they have to have a [stated] learning intention. For example, "doing long addition", but as soon as you have a narrow learning intention like that, you cut out the mathematical thinking, it suddenly becomes a process. (Narah INT2)

Making learning intentions explicit at the beginning of a lesson was also in clear conflict with the structure of Japanese problem-solving lessons, not only in terms of timing but also because in the Japanese model the mathematical goal of the lesson should emerge during *matome*, the climax of the lesson.

Nevertheless, many of the teachers in the project embraced the Japanese problem-solving lesson structure and planned to continue using it in their teaching.

> I see it as very exciting, I don't see us as having a usual structure for maths…. I see this structure though as really enriching… it means that problem solving isn't just that tack on at the end of the unit…. [Instead it] allows teachers to actually, to teach through problem solving, which is a far richer way to teach. (Narah INT3)
>
> I'm just doing a different structure. My kids are becoming better problem solvers and being able to better articulate themselves and share their thinking and how they've reached these outcomes…. [I am using this structure] about three times a week. (Lynn INT3)
>
> I like… the lesson structure… I've started using it in my own teaching now, as well, like having that summary, that longer summary period, and modelling it as "this is Sasha's way", and "Skyla's way", and the kids are starting to really pick up on that vocab[ulary] and using it as well. (Megan INT4)

4.2 Beliefs about learning and teaching

A major impediment, deeply embedded in the local cultural script for mathematics lessons, was the practice and associated belief that learning and teaching only took place during the phase of the lesson when students worked individually or in groups on the task presented to them by the teacher.

> I feel like I didn't get around to all the kids. So there could be in our planning ensuring that we're doing quick "roams" and all kids are being seen…. I spent a lot of time with Emily who came up with great generalisations … [but] maybe in our lesson [we need] to have a time of restock and extend them all … rather than doing it individually, so they all have that opportunity. (Lynn PLD1)

This was re-iterated by the knowledgeable other:

> My feeling was 25 to 30 min of individual work, where you had to work very, very hard going round, those productive discussions one-to-one were not able to be shared across the classroom. … So that's sort of my main point, very productive time, but a very busy time, and time intensive exercise for the teacher to go check everybody. (Max PLD1)

The reluctance of teachers to use the *kikan-shido* phase of the lesson for purposeful scanning rather than teaching also highlights the "collective versus individual orientation" (Watkins and Biggs 2001, p. 8) difference between Japanese and Australian culture, where in the latter *differentiation* is used in the teaching of mathematics to cater for individual differences.

Beliefs that underpin systemic differences, such as the layout of classrooms (c.f. Stigler and Hiebert 1999, p. 99) can exert a strong influence on pedagogy. In many (possibly most) Australian elementary school classrooms, not only do children sit at tables for 4–8 children, with many having their backs to the "front" of the classroom, but blackboards and large whiteboards have been replaced by single, relatively small, electronic whiteboards, possibly supplemented by a small whiteboard or even an easel with "butcher's paper". In a smaller number of schools, there has been a conscious decision to have no "front" of the room, in keeping with a prevailing view that instead of the teachers' role being that of "the sage on the stage" it should be "the guide on the side". These arrangements of tables and chairs make it difficult, if not impossible, for all children to participate in whole-class discussion (which itself is often equated with expository teaching) or even read solutions on the board when they are seated at their tables. The fact that the normal practice when sharing solutions was for children to sit on the floor at the front of the room not only made it difficult to have lengthy discussions, but also led to children having the expectation that the real lesson was over once they began sharing solutions.

The lack of a large blackboard, or other large display and writing space, also makes it impossible for students to view the entire lesson as it unfolds. While the basic ideas underpinning *bansho*—namely the need to plan the organisation of the board, including which anticipated student solutions to display, and in what order—resonated almost immediately with teachers in our project, they quickly realised the difficulties they would face in displaying and discussing student solutions in their classrooms. Immediately after the first planning meeting, teachers at the school where the meeting was held took the research team to see the classrooms that might be used for research lessons. They had already thought about how to create additional whiteboard

space and were planning how to attach student work to the boards. However they did not come up with a solution to the problem of having students seated on the floor, without access to writing materials, for the *neriage* and *matome* phases of the lesson.

Despite these constraints, teachers came to value the extended discussions, while students gradually became accustomed to participating.

> It probably gives more value to students sharing any of their work. And the value in that is instead of just having the one student who always shares, you have a selection… Having audience interaction I think makes everyone accountable and they're thinking more actively. (Keith INT3)

> It works and now that I've done it more with my kids they understand it better and they're getting used to the idea that, yep we're going to sit here and we're going to talk about [it]. And you can put ideas out there. You can discuss things. (Trevor INT3)

4.3 Kyozaikenkyu

Planning a research lesson requires deep *kyozaikenkyu* in order to match the mathematical goals of the lesson with the specific tasks for the lesson and students' prior knowledge.

An area where teachers struggled was in formulating learning goals—especially ones that related to mathematical learning rather than observable outcomes such as students finding and communicating multiple solutions to the problem or "demonstrating confidence" (FN, PM1).

> I found it surprising how hard it was for us to articulate what the goals of the lesson were going to be. I thought it would be pretty easy… [but] I was surprised how long we spent trying to articulate [these]….. But having said that it is obvious how important it is… to articulate just to yourself what your learning intention is for that lesson. And often what you say the learning intention is and then what you do in the lesson is very very different. (George INT2)

Finding suitable problems presented some difficulties. For the first lesson study cycle, the research team selected the well-known *Matchstick Problem* shown in Fig. 1.

While the two planning groups developed different statements of the problem (*hatsumon*), in both cases, not surprisingly, the lesson goals focused on problem solving (or process) goals, such as "Students use problem solving strategies to recognise a pattern and formulate generalisations"

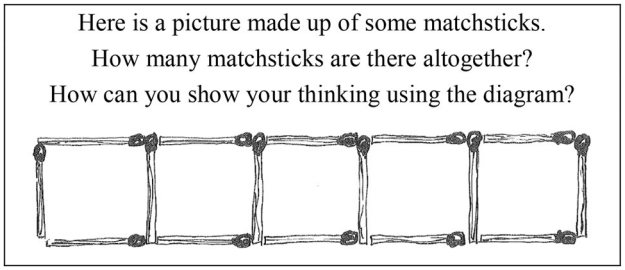


Fig. 1 The matchstick problem as presented in the first Year 4 research lesson (RL1)

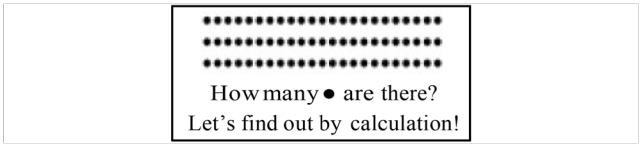


Fig. 2 A Year 3 multiplication task (Muramoto 2015)

(LP1). In Japan, such lessons are often referred to "jump-in" lessons—that is lessons that might occur at a number of different year levels as their content is not strictly tied to the curriculum. However, in Japan, structured problem-solving lessons typically include both content goals and goals relating to problem-solving skills and strategies, with Takahashi (2008) describing them as vehicles for introducing new topics or big ideas.

For the second lesson study cycle, participants requested a problem related to multiplication. The research team, with some difficulty, located the problem shown in Fig. 2.

However, participants would have liked to have found their own problems, as illustrated by Megan's response in Interview 4 to the question of what we should have done differently:

> I suppose in a way, like you guys giving us the questions has probably been helpful, but I think it would have been a bit more helpful if we could have been a part of actually that process of choosing the question. (Megan INT4)

As Yokosuka (1990) pointed out: "It is possible to explore the same subject matter with different *kyozai* [instructional materials], or we can investigate different subject matter with the same *kyozai"* (p. 19, translation cited in Watanabe et al. 2008). Not selecting the problem to match the learning goals for students, but instead trying to "retrofit" these to match the problem also increased the difficulties faced by teachers in articulating their learning goals.

> Probably looking at the problem itself and then trying to match it to specific goals and content area, that's probably been the most challenging. (Sandra INT3)

In Japan, with its tightly defined curriculum, there are only a handful of textbook series sanctioned for elementary schools, while the linked teacher support materials provide examples of anticipated solutions. In Australia, a national curriculum was first implemented in 2013. Textbooks are available in abundance, but they offer very little teacher support and rarely discuss the mathematics underpinning student activities. Consequently, there are few sources of problems suitable to use as single tasks to introduce units of work, as opposed to problem-solving tasks that focus solely on problem-solving processes.

5 Japanese Lesson Study as a model for teacher professional learning

Clarke and Hollingsworth (2002) maintain that teacher change is a non-linear process that occurs incrementally through the mediating processes of enactment and reflection, where the term enactment has been chosen to represent "the enactment of something a teacher knows, believes or has experienced" (p. 951). In this research project, teachers experienced what we hoped was as authentic an implementation of JLS as was possible, with participants enacting all its phases and having the opportunity to identify salient outcomes through reflection on the process. We argue that this iterative process of enactment and reflection was the critical factor in the participating teachers' professional growth. For further details of the way in which Clarke and Hollingsworth's (2002) *Interconnected Model of Professional Growth* was used to explain the mechanisms through which participants' professional growth occurred, see Widjaja et al. (2015). Here we will focus on some of the issues relating to adopting and adapting JLS in the Australian context.

5.1 Adapting lesson study

Hart and Carriere (2011) note that a first step in adopting lesson study outside Japan is to adapt it to include a study of JLS itself. In our project, the first half of the initial whole-day professional learning session was designed to introduce teachers to JLS, with participants also being provided with a number of readings about JLS. In the second half, the research team conducted a "mock" research lesson based on a task similar to *Matchsticks*, but at a more advanced level. This included an extensive lesson plan and post-lesson discussion, in order to "immerse the teachers in the concept before they begin the planning process" (Hart and Carriere 2011, p. 30).

A major difference between our project and what might be regarded as standard practice in Japan was that, due to their lack of experience with structured problem solving, teachers in our project found it particularly difficult to anticipate student solutions. They therefore decided to use other classes at the same year levels in their schools to trial similar problems, and even the same problem, as part of their planning for the first research lesson. Participants' reflections on these trials led them to note a number of outcomes, including the range of solution strategies used by students, and evidence that orchestrated whole-class discussion could be used in their classrooms. It also helped them identify questions they could use to elicit students' thinking, as well as providing them with anticipated solutions for their research lesson. Trialling problems became an embedded part of the adapted JLS process in all of the later research cycles.

Participants were surprised initially by many aspects of JLS, but on reflection strongly endorsed its value as a model for teacher professional learning.

> Initially that time spent in the planning didn't make sense. Why you would spend so much time? Then once you actually do the research lesson you actually realise you have more time to think about the lesson and the approach and the different things when you hear the feedback given at the end, because quite often the people giving the feedback pick up on things that perhaps we hadn't even discussed in that preparation time. It makes you realise just how much there is to the teaching and learning when you step back from the actual lesson or class itself… It has been the most valuable thing that I've done in my maths [professional] learning. (Sandra INT3)

5.2 Supporting lesson study

A major factor in the successful implementation of JLS as a model for teacher professional learning was the level of support provided by the school leadership teams, the project, and the network numeracy coach.

> For this model to be successful, you can't just have a few teachers who are like "Yeah, great, let's do it". It has to be supported, by the school leadership and by the system and it has to become kind of entrenched in what you're doing. (Narah INT3)
>
> We are very, very big on professional learning, leadership roles, and improving teaching and working collaboratively at that school. So I think this school really does have the perfect environment for lesson study… because it's so supported here. And it's

> expected of us to go out and do that professional learning. (Camilla INT3)

The fact that there were two teachers and one numeracy coach at each of the schools provided teachers at the same school with opportunities to trial and discuss changed pedagogy between the fortnightly cross-school meetings. For example, during the planning for the first research lesson, Lynn and Trevor observed each other's lessons, while Megan supported them in her role as numeracy coach. They video-recorded the trial lessons and discussed their observations. The lesson trial enabled the teachers to observe the questions used by colleagues to elicit students' reasoning and challenge them to justify their solution.

> Just the right question to ask to get them talk about their strategies because… I know… I am guilty of accepting what they said the first time or putting "this is what you did" rather than [them] telling us what they did. (Lynn, PM3)

The project was fortunate to be able to work in a school network where there was previous interest in JLS. The network numeracy coach had conducted some preliminary work with teachers previously, although she was severely hampered by the lack of resources to enable teachers to teach and observe research lessons (Palmer 2010). Her role in recruiting schools, supporting teachers, and liaising with teachers and schools throughout the project was invaluable.

During 2012, schools were provided with funding for teaching relief for a total of four days per classroom teacher to cover a range of activities including the professional learning day, the teaching or observation of the four research lessons, and participation in the subsequent post-lesson discussions. However, the four two-hour planning sessions for each of the two planning teams, each term, were intended to take place out of school hours. In fact, the network numeracy coach negotiated with schools to make arrangements to enable the classroom teachers to attend these meetings from 2 pm to 4 pm. (Australian schools usually finish at about 3:15 pm.) As a result, there was almost 100 % attendance at all planning meetings, as well as the research lessons and post-lesson discussions.

Possibilities for planning a research lesson, at least within schools if not across schools, already exist as there is planning time allocated during school hours and after school for year level teachers to plan in collaborative teams.

> The other strength is that it's a collaborative process, which is what we love…. It fits well within our professional learning community model and… [is] the key to us. (George INT3)

Collaboration was highly valued by the participants, not just at a superficial level.

> Collaboration doesn't mean someone else does the work for you and it's less work. It's about really challenging each other's thinking and questioning each other, and that's been a big feature of this. (Narah INT3)

However, a major constraint in the introduction of JLS is the problem of releasing teachers to observe research lessons and participate in post-lesson discussions. In Japan, research lessons are typically conducted during the last lesson of the day, with students in other classes being sent home so that all teachers can attend. This would not be possible in Australia.

> If you were to release twenty teachers at a school, or ten, you know it could get quite costly. So that's something that would need to be fixed or adjusted for this complex model. (Keith INT3)I think one concern that comes to mind was the fact that some of the teachers that watched the lesson didn't come to the post-lesson discussion, so that… I think they've just seen one snapshot of it. (Megan INT4)

5.3 Creating a sustainable lesson study culture

While much of the literature relating to adaption and adoption of JLS seems to focus on the value of collaborative planning and receiving feedback through the post-lesson discussions, there is much less emphasis on the value of these for all participants in the discussion.

> I think the quality of the discussions are important because if they don't learn from those discussions… they won't necessarily see the value… I think we're all here for the students, so if they see what more you can learn from the students, making the observations and hearing from other people about what's going on about their students, I would hope that that would convince them what they can learn for their students. (Sandra INT3)

Prior research suggests that, without a tradition of lesson study or structured problem-solving lessons, successful adaptations of JLS have frequently depended on the involvement of Japanese teachers and educators (e.g. Robinson 2007; Inoue 2011), while Hart and Carriere (2011, p. 37) highlight the importance of having a knowledgeable other who supports "the values of lesson study: A culture of self-criticism, openness to the ideas of others, and willingness to embrace mistakes".

All four members of the research team had visited Japan and witnessed many examples of JLS, while both

"knowledgeable others" were experts in JLS. Participating teachers highly valued the post-lesson discussions and regarded Professor Fujii's involvement in these as an important learning opportunity.

> I think they were really beneficial and positive. What I've noticed is, sort of the culture that sits behind it. I can imagine the Japanese post-lesson discussions being a lot more, as I said honest, really perhaps a little bit more animated, a bit more challenging. I think we're very polite here. And I know Japanese are polite, but I have a feeling they're a bit more blunt in this context. So that really stands out to me, as the culture of where that discussion is happening. So therefore that whole thing of changing the culture at the school, to support this model, would result in the best possible discussions, that culture of giving and receiving feedback. (Narah INT3)
>
> Having someone like Toshi here today… when he was speaking everyone was listening… I like his approach. I know with sport… that's the feedback I like…. it can be harsh at times and you probably don't want to hear what some of them are saying. But these people are here for a reason – like you guys haven't invited any Joe Blow off the street to come and give advice. (Trevor INT3)

As Stigler and Hiebert (1999, p. 138) point out, the "system for improving teaching, just like the system of classroom teaching, is a cultural activity", with Japan adopting a model of continuous, incremental improvement, in contrast to the constant change, which in some other countries leads to teacher resistance and superficial adoption. Participants in lesson study see themselves as knowledge producers who contribute to knowledge about teaching as well as pursuing their own professional learning (Stigler and Hiebert 1999). To support the sharing of the results of lesson study, funding was made available in 2012 for all participating teachers to attend one of the days of the state mathematics education conference, with participants from each school presenting a seminar together with one or two members of the research team—a total of three presentations. The remaining three joint presentations in 2013 and 2014 were given by members of the research team together with Paula and George.

While the school region supported the continuation of the 2012 project, offering two full days of teacher relief for each participant, which was taken up by two of the three schools, as mentioned earlier there were major staffing changes at all three schools that made continuous improvement difficult. Megan, the numeracy coach at one of the 2012 schools had moved to a new school with no history of lesson study and no longer had a full-time numeracy coaching position. Narah, the curriculum specialist at another 2012 school, was on maternity leave and was replaced by Colin, a relatively new teacher at the school who had not taken part previously in any lesson study. George, the numeracy coach at the third school, while leading a lesson study cycle in Term 2 of 2013 and continuing his interest in lesson study, was promoted to principal positions at different rural schools from the middle of 2013.

> Losing [the third school]… we lost George, and Sandra, and Keith. But we also lost Narah. And I think… you've needed myself, Narah, and George, with a bit more experience. Everyone – the teachers have come a long way and have been brilliant, but I think they've sort of needed that leadership… So, I think losing all of them, and then gaining Colin, who has sort of come in with no real background, I think it would be probably a bit difficult for him. (Megan INT4)

This raises many issues regarding sustainability of JLS as a model for teacher professional learning in Australia. For sustainability, it will be necessary to establish a community of teachers, mathematics educators and researchers who can continue the process, including providing initial exposure to lesson study and acting as outside experts at post-lesson discussions. The fact that there were 30 observers at our last 2012 research lesson suggests that there is significant interest and offers hope that a lesson study culture could be built up over time.

6 Conclusion

Despite its long-standing tradition in Japan, JLS is undertheorised, with Elliott (2012, p. 114) commenting that while "lesson study has helped to construct shared knowledge about how to teach, particularly in Japan, 'the pedagogical theories' that underpin such knowledge building are often implicit and unclear". Research into lesson study only commenced in Japan as a result of the interest shown by Western nations, with Fujii (2014) noting that in Japan "lesson study is like air, felt everywhere… [but] so natural that it can be difficult to identify its critical and important features" (p. 66). Elsewhere, while many studies of professional learning programs have provided evidence of improved teacher learning, few have differentiated critical elements that have contributed to this learning.

In this paper we have discussed key features of JLS, described an attempt at a high fidelity implementation of JLS based on these key features, and identified some of the critical elements in that implementation. Participants spent eight hours planning each research lesson, as well as time between meetings. While this was regarded

initially as excessive, in hindsight participants realised the value of producing a lengthy, detailed lesson plan that included careful consideration of the mathematical goals for the lesson, the statement of the task, the place of the lesson within a unit of work and the broader curriculum, students' prior knowledge, and students' anticipated solutions. They also valued highly the post-lesson discussions, including the presence of large number of observers and, in particular, the insight provided by the "knowledgeable other". Teachers unanimously reported major changes in their pedagogy, including incorporating substantial time for the sharing of solutions, attempting to anticipate student solutions, and planning questions and probes to elicit explanations.

However, a major constraint to a high fidelity implementation of JLS was the difficulty in finding suitable tasks to match the Australian curriculum. This is possibly the most difficult aspect to remedy in the short-term as task design is a relatively unknown skill outside Japan, with some exceptions such as Watson and Mason (2006) and Swan (2008).

A further constraint was the teaching culture that emphasises small-group rather than whole-class teaching. This was evident in the research lessons when the teacher felt obliged to teach "mini-lessons" to small groups (or even individual) students during the *kikan-shido* phase of the lesson.

While teachers frequently referred to their experience of lesson study as being their most valued professional learning, further research is required to establish the development of sustainable lesson study groups within the Australian school culture—ones that do not rely on the degree of support provided in this project. This may be the single most critical structural factor in the implementation of JLS in Australian schools.

Clearly the cultural differences between Japan and Australia are of critical importance in a faithful implementation of JLS in Australia. However, as demonstrated by this project, changing the teaching environment is not impossible, but overcoming long-term cultural practices may be a more serious obstacle. By identifying features of the learning and teaching environment required for lesson study and the Japanese problem-solving lesson structure, findings from this project provide evidence for key foci that need to be part of a sustainable model of JLS for teacher professional learning. Moreover, while the focus of this project was on the implementation of JLS in the Australian context, the findings also have implications for its implementation in other countries.

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